THE WORLD OF WATERS;

OR,

RECREATIONS IN HYDROLOGY.

BY

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LONDON:
JOHN W. PARKER, WEST STRAND.

M.DCCC.XLIII.

LONDON:
HARRISON AND CO., PRINTERS,
ST. MARTIN'S LANE.

PREFACE.

Having on former occasions attempted to introduce our readers to the Earth as it is, in our *Recreations in Physical Geography*, and to the Earth in its former condition, in our *Recreations in Geology*, it is our present design to invite them to cultivate some acquaintance with the World of Waters. In this undertaking, our attention has not been limited to the consideration of the laws of Hydrostatics and Hydraulics, nor yet to a description of the more remarkable hydrographical features displayed in the Natural World, but it has been our endeavour so to combine the two subjects, that their connection may be clearly exhibited, and that they may thus tend to illustrate each other. Such being the plan of the present work, it will be obvious that it became necessary to select some appropriate name, some comprehensive term, expressive of the range of our subject matter. We have accordingly been induced to adopt the title, Recreations in Hydrology. But, lest any

should be scared by the technicality of this name, we have added the prefix of THE WORLD OF WATERS; not, however, without some hesitation; because the vastness of the theme implied by the latter title, leads us to feel that in the limits we have here assigned to ourselves, it is impossible to do justice to so mighty and so highly interesting a subject.

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CHAPTER I.

INTRODUCTORY REMARKS.

Water may unquestionably be regarded as one of the most remarkable as well as most important substances in nature. In selecting this valuable material, and the laws by which it is governed, for our present subject of consideration, we therefore feel confident that we are preparing for our readers a source of mental gratification, which, if not debarred from the natural supplies surrounding us on every side, will expand into a copious stream of important and highly interesting knowledge, forming a tributary to the "great Ocean, Truth."

The extreme utility of water is so apparent even to the most superficial observer, that it may appear almost superfluous to dwell on this point. All are aware that this fluid is absolutely essential to both animal and vegetable existence; that, if supplies of water are even temporarily withheld, all nature languishes; plants droop and wither, animals become feeble and dispirited, and, if subjected to long-continued drought, all organized beings perish*.

The value of water as a nutritive or alimentary substance may thus be considered as extending to the vegetable as well as to the animal world; to the lowest as well as to the highest inhabitants of the terrestrial globe; to the hyssop on the wall as well as to the stately cedar on the mountains of Lebanon; to the monas and to man. There are, however, other important

* Some exception to this general rule appears to be presented by the preservation, in the dry mud of lakes and ponds, of certain species of animals in an inert state, and their restoration to vigour on receiving new supplies of moisture. This, however, can scarcely be regarded as an exception, for water is evidently essential to their performing any of the functions of life.

and highly useful purposes to which this liquid is applied, which are more or less dependent on the exercise of the intellectual faculties. Such are its use in various arts and manufactures; its application as a motive power; and finally, its adoption, when occurring in large bodies in the form of rivers, lakes, and seas, as a medium for the more rapid or more advantageous transport of goods or persons from one locality to another, and thus, in many instances, affording the means of establishing an intercourse between distant regions of the globe, which, but for the facility with which water is traversed, would be for ever separated from each other, and debarred from the benefits arising from the interchange of productions, and the progress of civilization.

The use of water for the latter purpose, and the consequent construction of vessels, rude indeed, but nevertheless not ill adapted to the purposes for which they are designed, may be observed to prevail amongst almost all barbarous nations inhabiting the borders of the sea or of navigable rivers; and it is a fact worthy of notice, that nations so situated, are usually found to be more intelligent and further removed from barbarism, than those which reside in the interior, and have not the same motive to exert their skill and employ their mental faculties. This has been especially observed by Captain Fitzroy, in reference to the natives of Tierra del Fuego, and by Captain Beechey, with regard to some of the Esquimaux tribes inhabiting the western shores of North America. Striking proofs are these of the beneficial results accruing from incitements to industry, which may tend to rouse man from his natural indolence, and thus call forth his energies. Tribes or nations so placed have also usually more frequent opportunities of intercourse with neighbouring tribes or nations, than which, perhaps, nothing has a greater tendency to forward the progress of civilization. The circumstances most favourable for the advance of knowledge,—and in this may be included every description of art and science,—will indeed be those which lead to the establishment of free intercourse among nations, and when each has the opportunity afforded it of profiting by

the benefits arising from the useful inventions and brilliant discoveries of its neighbours.

> Trade to the good physician gives her balms;
> Gives cheering cordials to the afflicted heart;
> Gives to the wealthy, delicacies high;
> And when the Priest displays in just discourse
> HIM, the all-wise Creator, and declares
> His Wisdom, Power, and Goodness unconfined,
> 'Tis Trade, attentive voyager, who fills
> His lips with arguments.

It will be readily seen, that in our sea-girt island, it is solely by water communication that we can obtain these advantages; and we may further add, that it is by such means alone, by the interchange of knowledge, and by the experience of centuries, that ship-building has attained the perfection to which it has been carried in this and some other countries. It is true that

> The glittering ship, which hath the plain
> Of ocean for its own domain,

does not belong to our present inquiry; but since the laws by which floating bodies are governed, will engage some of our attention, it will be evident that even this is not wholly unconnected with our subject. And we shall readily perceive, that although constructed in the rudest manner, and without the artificer being aware of the existence of any established law, the coracle of the ancient Briton, and the canoe of the Indian, no less than the superb man-of-war, must be formed on principles in accordance with the fundamental laws of hydrostatics.

It has just been stated that water is not only one of the most important, but also one of the most remarkable substances in nature. The more detailed explanation of this observation must be reserved for a future page; at present we shall content ourselves by calling attention to one remarkable feature, namely, the circumstance of its occurring in three forms, *solid*, *liquid*, and *aëriform;* or, in other terms, as ice, water, and vapour: variations dependent mainly on a greater or less degree of temperature. Water may be considered as the natural or normal state of this substance; ice and vapour, but more especially the former, as incidental changes in its condition; ice, although

evidently acting an important part in the economy of nature, not appearing to be absolutely essential to the continuance of the earth in its present condition. The various phenomena presented by vapour, or atmospheric moisture, on the other hand, appear to be so intimately connected with the existing order of things, and with the well-being of the present inhabitants of the earth's surface, that we cannot suppose their continued existence, without that of water in its aëriform as well as in its liquid state.

Such being the importance of water, we shall be led to expect that the wise and beneficent Author of nature, who "created the earth to be inhabited," will have provided an abundant supply of so valuable a substance; and, accordingly, we find that the quantity of water on the surface of the globe is proportioned to its utility, this liquid being one of the most universally diffused bodies in nature. To the subject of its extreme universality, we shall have occasion again to recur; and with regard to its abundant diffusion, we need only remind the reader of the vast expanse of the ocean, the waters of which, independent of rivers, lakes, and other smaller collections of water, occupy nearly three-fourths of the surface of the terrestrial globe. Thus, the whole area of the earth's surface being estimated at 197,000,000 square miles, the space covered by the ocean is computed to amount to 144,000,000 square miles, and that occupied by the land not to exceed 53,000,000 square miles.

It may well be supposed, that a consideration of the phenomena presented by so remarkable a substance as water, and of the laws by which it is governed, must form a subject of great interest: it also includes much of extreme utility; and this, not only in a scientific point of view, but also in the more ordinary daily occupations of domestic life. The literal meaning of the term HYDROLOGY is "a discourse upon water;" such is the object of the present undertaking; and our endeavour will be to form, not a dry scientific treatise, but, whilst placing before our readers some sketch of the laws of hydrostatics and hydraulics, not to confine our attention to pumps, and cisterns,

and hydraulic engines, but rather, as far as our subject will admit, to select our examples from the natural world. We shall subsequently be led to take a brief review of the most remarkable phenomena presented by water on the surface of the globe, in springs, rivers, lakes, and seas; a branch of our science which may be distinguished by the term *Hydrography*. The phenomena of vapour or atmospheric water, belong to meteorology, rather than to hydrology: on this point we shall therefore limit our notice, to such remarks as bear more especially on our present subject of consideration.

CHAPTER II.

THE CIRCULATION OF THE WATERS OF THE GLOBE.—COMPOSITION OF WATER.—ITS FLUIDITY.—PECULIAR NATURE OF WATER.—ITS UNIVERSALITY; AND IMPORTANCE.—ATMOSPHERIC WATER.—SPRING WATER.—HARD AND SOFT WATER.

"To whatever department of physical science our remarks have extended," observes Dr. Roget, "we everywhere meet with the same regularity in the phenomena, the same simplicity in the laws, and the same uniformity in the results:—all is subordinate to one pervading principle of order." In no department of natural science is this pervading principle, this regularity of the phenomena, simplicity in the laws, and uniformity in the results, more evidently and strikingly displayed, than in the beautiful circulation of the waters of the globe.

The ocean, which has been aptly termed the "well of fountains, the pond of the world," forms a vast reservoir, from which supplies are drawn to water and refresh the whole of the dry land. This is effected by the simple process of evaporation. From the surface of this great expanse of water, moisture is continually ascending in the form of vapour. This vapour, which is lighter than common or atmospheric air,

rises to the highest limits of the atmosphere, and pervades it throughout its whole extent, a certain portion being always present in the atmosphere. The air, however, will not hold above a certain portion of vapour (the quantity varying with the temperature of the air), and when vapour is in excess in the atmosphere, it either descends to the ground in the form of dew, or collects into clouds, and is carried in those "light and fleecy magazines" over the surface of the globe, again to revisit earth in the form of rain, hail, or snow, and ultimately to return to its parent ocean. Of the water which thus descends to earth, only a small quantity, however, returns directly to the sea, the greater portion having an important part to perform in the economy of nature, ere it is permitted again to repose in the bosom of its mighty parent. Thus, to one part is assigned the task of imparting moisture and consequent fertility to the land; another part enters into the composition of animal and vegetable bodies; whilst another sinks into the earth, through porous rocks, or through crevices, and there accumulates, forming subterranean reservoirs of water. These subterranean reservoirs give rise to springs; and no sooner do these springs make their appearance on the earth's surface, than this portion of water may be regarded as commencing, with what speed it may, its return to the ocean. The conjunction of springs, aided, in most cases, by the occasional addition of rain-water or snow, forms brooks or rivulets. These streamlets soon unite with others, until rivers are formed, of various degrees of magnitude. These, after dispensing innumerable benefits to the inhabitants of the districts through which their course lies, in the greater number of instances eventually flow into the ocean, once more forming a portion of the mighty deep, until the water is again evaporated into the atmosphere, "to pass and repass through the same cycles of perpetual circulation."

This perpetual circulation of the waters of the globe is not less remarkable than admirable, from its peculiar and beautiful adaptation to produce the beneficial effect of preserving water in a pure state, a result highly important, if not absolutely

essential, for maintaining the health of the natural world. Water, from its tendency to act upon various substances, and either to unite with, or to hold them in solution, is continually subject to become corrupted and unfit for the purposes of life. By the process of evaporation, however, water rises pure and untainted from the sulphureous spring, from the salt ocean, and from the stagnant ditch; again, perhaps, to rest upon the earth in the form of the purest dew. The advantages accruing from this circumstance, whether to man or to the whole natural world, are beyond calculation. Thus, with regard more especially to man's benefit, the fact of water readily combining with various substances, imparts to this liquid its value in the greater number of arts and manufactures, and also renders it available in culinary and other processes, not only as a means of softening and preparing food, but also for its cleansing properties, without which our plates, and dishes, and saucepans, would not present a very gratifying aspect. If, however, the soiled water which had been used for cleansing these and such like articles, were to rise into the atmosphere impregnated with grease; or, to take a less extreme case, even if sea-water were to ascend from the ocean, charged with saline matter, and as a necessary consequence, if rain-water and dew were imbued with these or any other equally deleterious foreign ingredients;—alas, for vegetation! alas, for ourselves! in a very short space of time the whole face of nature would be changed, the beautiful trees and herbs which adorn this terrestrial globe would disappear, and man himself would perish.

This beautiful circulation of the waters of the globe may also, perhaps, be considered as the means appointed by the Author of nature, for securing the permanency of so important a substance as water. For it is evident, and this may be considered as one of the remarkable features of this liquid, that, amid all the changes and revolutions which have occurred on the earth's surface, water has maintained the same characteristics that it exhibits at the present day. This circumstance has been shown by the recent investigations of science, and more especially by those of geology; for it appears that water, bearing

the closest resemblance to that of our rivers, lakes, and seas, must have existed during the remotest geological epochs. This is proved by the various phenomena exhibited by stratified rocks of all ages, these being either formed or modified by aqueous action, and in some instances by the agency of ice. Geology also informs us that animals and plants differing from, but bearing a close analogy to, those at present inhabiting the terrestrial globe, have at all those periods tenanted the land or the water. And it will be evident that neither of these classes of organized beings could exist without the same valuable liquid, which is now absolutely essential to the welfare of their living prototypes.

We may, therefore, reasonably infer that then, as now, rain fell from above, springs issued from the ground, torrents dashed down the rocks, and rivers traversed the plains; that tranquil lakes existed, and that an ocean both flowed into estuaries, and spread its deep salt waters round clusters of islands. And, yet further to confirm this interesting conclusion, optical science has lent its aid to geological research, and by the discovery in a perfect state of preservation of the eye of the trilobite, (an extinct species of crustacea, inhabiting the ocean during very ancient geological periods,) as well as that of other animals belonging to intermediate periods of geological history, physiologists have been enabled to trace in these fossil remains "the same modifications of sight as in the living crustacea." "These results," observes Dr. Buckland, "prove the ancient condition of the sea and atmosphere, and the relation of both these media to light; for in those remote epochs, the marine animals were furnished with instruments of vision in which the minute optical adaptations were the same, as those which impart the perception of light to the living crustacea. The mutual relations of light to the eye, and of the eye to light, were therefore the same at the time crustacea first existed at the bottom of the primeval seas, as at the present moment." It thus appears evident that the primeval seas and the atmosphere, must have been similarly constituted with those of the present era; and accordingly we have an incon-

testible proof of the antiquity of water, presenting similar phenomena with those exhibited by the water at present so bountifully supplied on the face of the globe, and without doubt passing through the same perpetual and beautiful circulation. And thus, although we may not concur in the opinion of Thales, that water was the origin of all things, we cannot but conclude that, beautifully adapted and needful as is this liquid to the existing order of things, it can have been no less so to organized beings in the most remote periods; and, therefore, "In the beginning," when "God made the heaven and the earth," He also created the waters.

But permanent as water appears to be, it is capable of decomposition. It was, nevertheless, long considered as an elementary or simple substance, and it was reserved for our countryman, Cavendish, to prove, by direct experiment, its precise composition. Water is found to be composed of two gases, oxygen and hydrogen, in the proportion of one *volume* or bulk of oxygen, to two volumes of hydrogen. The relative weights of a volume of oxygen and one of hydrogen, however, differ greatly; hydrogen being the lightest known body in nature; whilst a volume of oxygen is sixteen times heavier than a volume of hydrogen of equal bulk. And, accordingly, although the proportion *in bulk* of the hydrogen is greater, its relative *weight* is eight times less than that of the oxygen, the consequence of which is, that a minute particle of aqueous vapour is, bulk for bulk, lighter than oxygen gas.

Independently of their ultimate subdivisions into elementary parts, all bodies are capable of the most minute subdivision. In solid bodies, these minute particles are naturally fixed and immoveable; but in water, and other fluids, *these parts are perfectly moveable among one another by the slightest partial pressure.* And thus, if we immerse the finger in a glass of water, the water yields to the pressure, however gentle it may be. The motion thus imparted to a limited portion of the water, or to a certain number of these minute moveable particles, is also transferred *to all other parts* of the mass of water; and accordingly we find that the whole of the water in the glass becomes

agitated. The cause of this perfect freedom of motion in the particles of water, or, as it is termed, its *fluidity*, and which is common to all fluids, is perhaps not yet distinctly understood; but it is supposed to arise from the almost total absence of friction, water being considered to consist of a collection of infinitely small, smooth, and spherical particles, of equal diameter and equal weight or *specific gravity*, which move freely among each other. On account of their smoothness they are supposed to slide readily over one another, whilst their sphericity prevents them from touching one another in more points than one; and by both these qualities their friction is rendered the least possible. Accustomed as we are to regard water as an entire, though yielding substance, its divisibility, and the perfect freedom of motion among its particles, might at first sight appear contrary to what may seem the evidence of our senses; and yet we have proofs of this divisibility daily presented to our own observation, in the process of evaporation. If we, for instance, pour a little water on a marble slab, we are well aware that in the course of a greater or less period of time, the liquid will be dried up or evaporated. But, let us inquire, what becomes of the water? How does it take its departure from the slab? Do we see it ascend into the air of the apartment, quitting the marble slab in a body, like a bird or a butterfly? Assuredly not. But what does become of the water? All we can reply (according to the evidence of our senses), is, that the water is gone, we know not how or whither. The fact is, that the particles of water are so minute, that they are imperceptible to our vision; and, consequently, as the water is evaporated or dried up, they (being as we have just seen lighter than common air) ascend, and float in the room, without our being conscious of their presence. These minute separated particles of water constitute what is termed aqueous vapour: and water is formed by an aggregation or collection of these particles, which are kept together by the law of nature, called the *attraction of cohesion*.

In water, this attraction is far less powerful than in solids, the consequence of which is, that, although under particular

conditions, these particles remain firmly united together, forming the substance called water; yet, if these conditions are altered, this attraction ceases, and the minute particles are left free to disperse themselves in all directions. That the attraction of cohesion is much less forcible in water than in solids is evident by the circumstance of the water evaporating from the marble slab; for, were it otherwise, either the water would remain as permanent as the slab itself, or the latter would gradually disappear. With regard to the subject of our present inquiry,—water,—the attractive force has not sufficient power to retain the minute particles on the outer edge or surface of any mass of the fluid; these are therefore continually flying off, thus giving rise to the phenomenon called evaporation. As long as the particles are kept together by this attractive force, so long do they constitute the *non-elastic* fluid called water; but the moment the attraction ceases, and they are disengaged and free, the same moment do they change their character, and become transformed into the *elastic* fluid termed vapour.

We have seen that the attraction of cohesion is dependent on certain conditions: one of the most important of these is temperature. In water, the attraction of cohesion is greatest at the temperature of 40° Fahrenheit; or, according to the recent investigations of Professor Stampfer, of Vienna, 38° 75′, which would make it a degree and a quarter lower. Be this as it may, it appears evident that, at the particular temperature at which the particles are drawn nearest together by the attractive force, at that temperature, will the liquid be the most dense; and thus, being more compact, it will be of smaller dimensions, and its weight or *specific gravity* will be greater. As the temperature is augmented, the minute particles being less closely united or drawn together, the liquid becomes lighter: and thus, if heat be applied at the bottom of a vessel, the water in that part will become *specifically* lighter, or, in other terms, it will be lighter, bulk for bulk, than it was before, and than an equal bulk of the cold water in the upper part of the vessel. Now, as it is a general law, that all heavy bodies will, if they have freedom of motion, sink to the lowest possible place they

The fact of the interchange of the particles of water when heat is applied at the bottom of a vessel may be verified by a very simple experiment. Having procured a common glass phial, let us first pour into it a small portion of water, to which we have previously given a sufficiently deep tint, by mixing it with indigo or some other colouring matter. Let us now fill the phial with clear water, pouring the latter in with so careful a hand, that the coloured water may remain as a distinct mass or band, at the bottom. Let us now insert the lower end of the phial in a cup of hot water; and as the water becomes heated, we shall see the portion of the water in the upper part of the phial descend, and change places with the coloured water, with greater or less rapidity, according to the degree of temperature we may apply at the bottom of the phial. It will be readily seen that a similar effect will be produced, whenever a kettle filled with cold water, or, indeed, with water at any temperature below the boiling point, is placed upon the fire.

One great advantage arising from this interchange of the cold and warm portions of water from the top to the bottom of a vessel, is the rapidity with which water can in consequence be heated: a circumstance, which, we may all know, is of no small importance to the comfort, and even not unfrequently to the well-being of man, especially in cases of severe and sudden illness. But, in order to warm water with rapidity, heat must be applied to the lower part of the vessel; for if, for instance, the hot water were to be applied at the top instead of at the

bottom of our phial, the portion of water which would become heated and consequently lighter, being, in this case, in the upper part of the phial, would, instead of descending and thus changing places with the water at the bottom, yet more determinately maintain its position at the top, and the water at the bottom of the phial would only become heated by a very slow process, called *conduction*, that is, the communication of heat from particle to particle; and as water is a bad conductor of heat, (a circumstance of extreme utility in the natural world,) a considerable length of time would elapse before the whole of the water would become equally heated.

When aqueous vapour ascends into the atmosphere, it assumes, as we have seen, the form of an elastic fluid, and becomes dispersed over all parts of the atmosphere. By some process, perhaps not yet fully explained, but evidently in great measure dependent on diminution of temperature, the particles of aqueous vapour unite, and again become visible, either in the form of steam, or in that of mists and clouds: and further, when a large number unite, and become condensed, they fall to the ground in the form of rain, hail, or dew; thus again appearing as water on the surface of the globe, once more to pass through the same processes of evaporation and condensation, though perhaps in a different hemisphere.

We have seen that the density of water is affected by temperature, and that it attains its maximum or greatest density, at a few degrees above the freezing point. Now, it is a general law that all bodies, in every state of aggregation, whether solid or liquid, expand by heat, and contract by cold. To this general law, water forms a very remarkable exception. Like all other bodies, this liquid, as we have seen, contracts with a decreasing temperature, until it reaches that of about 39° Fahrenheit, or about 7° above the freezing point of water. Having arrived at that temperature, however, instead of following the apparently general law, and decreasing yet further in its dimensions, it, on the contrary, begins to expand; and this gradual expansion continues until congelation occurs, when, at the moment of freezing, a more sudden and considerable expansion

takes place. The density or specific gravity of ice is consequently decidedly less than that of water at the temperature of 39°; and accordingly, ice will float on the surface of water at that temperature. The specific gravity or weight of water at 39° being reckoned at 1·000, or *unity*, that of ice at 32° does not (according to recent experiments by Osann) exceed 0·930, or a little more than nine-tenths of the specific gravity of water. This observation, however, only refers to water at that particular temperature, for at higher temperatures the specific gravity of water will be lessened; and according to Professor Johnston, the point of temperature at which water acquires the same absolute magnitude as at 32°, is about 46°. Water above that temperature will therefore be lighter than ice, which latter will of course no longer float on the surface.

Although its importance may not at first sight be apparent, the peculiarity in water above noticed, in which it exhibits a departure from the general law of nature, leads to effects so obviously wise and beneficial, that it affords one of the strongest and most impressive of those endless proofs of design and watchful providence which present themselves on all sides to the attentive observer of the works of nature. Indeed, as Dr. Prout has well observed, "the importance of this anomalous property of water is so great, that it is doubtful whether the present order of things could have existed without it; even though everything else had remained the same." "For instance," he continues, "were it not for the comparative lightness of ice, this solid, instead of beginning to be formed at the surface of water, would have begun to be formed at the bottom, as the colder water, from its specific gravity, would naturally have sunk. For similar reasons, the lower stratum of ice would have been the last to have melted. Now, let us reflect for a moment on the consequences of such an arrangement. In the northern, and even in temperate climates, the bottoms of all lakes and deep waters would have been a mass of ice, and totally inaccessible therefore to organized beings. During the summer, a few feet of the upper part of the ice would perhaps have been melted; but what little had been melted in summer, would

again have become solid during winter; and as the accumulations of ice would have been constant, all the seas, even perhaps to the tropical climates, at least at their bottoms, would, long before this time, have been a mass of ice!" Dr. Prout then proceeds to show, that in consequence of the above anomalous properties of water, not only is all this evil prevented, but much that is beneficial accomplished; for not a particle of ice can be formed on a lake or other collection of water, until the whole mass is cooled down to about 39°; that is, until the whole mass has acquired the greatest density or specific gravity, water is capable of attaining; for, until this is effected, the warmer particles will continue rising from the bottom, and prevent the formation of ice. The cooling down of the liquid in such a collection of water, is effected in a manner analogous to the heating the water in our phial, only by an opposite process; that is, by the application of cold at the top, instead of heat at the bottom, the one, like the other, causing an interchange of particles to take place, although with less rapidity, until the whole becomes of equal temperature. "If the depth of the water be considerable," further observes Dr. Prout, "the application of cold may be long continued, without the result of freezing; hence in this and other countries not intensely cold, it often happens that deep lakes remain unfrozen during the coldest winters."

We have made some slight allusion to the extreme universality of water; and upon further inquiry, we shall find this assertion verified, for in fact, almost wherever we turn in the natural world, there is water, acting an important part, although perhaps not always obvious to the superficial observer. Thus, (as we have already seen,) water is always present in the atmosphere. It forms the chief ingredient in the animal solids as well as fluids; so that that even a dry bone, when distilled, yields a certain portion of water. The sap of plants is found to consist of water, mucilage, and sugar, with some saline particles; but the principal ingredient is water. "Even the most compact rocks," observes Mr. Lyell, "may be regarded, before they have been exposed to the air, and dried, in the light of

sponges filled with water." We thus find that our liquid forms a constituent part of the atmosphere which surrounds our globe; of all the organized beings which adorn its surface; and even of the rocks which exist in the interior of the earth.

Obvious as the importance of water must be to all, its extreme value as a beverage to man can, perhaps, be only fully appreciated by those who have at some period endured a privation from this truly inestimable liquid. Accustomed as we are, in almost every part of these favoured isles, to abundant supplies of good and wholesome water, it is by no means impossible that we may sometimes overlook the greatness of the blessing thus accorded to us, and use it from day to day, and from year to year, without entertaining any adequate notion of its real importance in this respect. A recent traveller, on his return to this country, after having traversed desert tracts, found nothing so striking as the profusion and negligence with which water seemed to be lavished; an article which he had been in the habit of guarding, as the most precious of his provisions. Few of us, perhaps, ever experienced real thirst; and it may be difficult for those who have not, to form any idea of the sufferings endured by those who are exposed to this privation; whether in crossing the parched and sandy desert, the broad savannah, or the briny ocean. All water, as is well known, is not equally adapted for use as man's beverage: and not only is sea-water unfit for this purpose, but salt springs and salt lakes occur in many parts of the globe, the waters of which are quite undrinkable. And perhaps we cannot picture to ourselves a more pitiable situation for a traveller to be placed in, than, when wearied with a long journey across an arid desert, and fainting with thirst, he arrives at the margin of a lake, and instead of meeting with wholesome fresh water, he finds its waters saline and wholly unfit to drink. Yet it not unfrequently occurs, that in sandy deserts the lakes are of this description. And even in less arid districts, the want of good water may be little less distressing; for in the latter case the traveller is more unprepared to meet the evil; and how great must be his disappointment on arriving at spring after spring,

to find the water brackish, and unfit for use. Such, however, Mr. Schomburghk found to be the case in the savannahs of British Guiana. The mariner also, whilst crossing the watery main, may be exposed to a similar state of distress if his supplies of fresh water are exhausted; and surrounded though he may be, by the waters of the mighty reservoir by which the whole world is watered and refreshed, he is in danger of perishing:

Water, water, everywhere,
But not a drop to drink.

"Hungry and thirsty, his soul fainteth within him;" and although aware of the fatal consequences likely to ensue, he is at length perhaps driven to the fearful alternative of seeking to allay his thirst by drinking the saline waters of the ocean. Oh, who can sufficiently estimate the value of a little fresh water at such a moment, and under such circumstances! How highly would the poor fainting mariner prize many a portion of water which we too often inconsiderately use, or even heedlessly waste! Let us not, however, be misunderstood: we do not design to infer that what appears by such contrast to be wasteful is, in fact, reprehensible; far from it; for our economy in this respect would not alleviate the sufferings, or supply the wants, of the perishing mariner. And, since in this happy land God hath given us this blessing freely to enjoy, let us not scruple to take full advantage of it; but let us make ourselves acquainted with its uses and properties; and whilst considering its beauty and its value, let us receive the boon with feelings of admiration for its adaptation to the benefit of man, and with gratitude to Him who so created it.

We have pictured to ourselves the mariner and the traveller almost perishing for want of water; let us conjure up a more grateful scene, and behold them receiving supplies of fresh water. From that vast reservoir, whose waters it is almost worse than death to drink, pure water has risen by evaporation, it has collected into clouds, and lo, these bottles of heaven are opened, and they pour down grateful supplies for the poor perishing mariner; his strength is renewed, and he is enabled to reach "the haven where he would be." Let us again pic-

lves the traveller crossing an arid desert; but let us of a saline lake, suppose him to behold a distant fine stream under any circumstances presents a beau- and attractive object, but how incalculably must these be enhanced when the traveller is almost perishing want of water! With what delight and enthusiasm did Burchell, whilst travelling in Southern Africa, when he had been compelled from the want of that all-important article, to proceed with distressing rapidity over a vast expanse of the parched and desert karroos—with what delight did he hail the beautiful river Gariep! And cold, indeed, would be that heart, which in such a moment did not experience some emotions of gratitude to the Giver of all good.

We have seen that evaporation acts a most important and beneficial part in the natural world, by raising water fresh and purified into the atmosphere, from whence it again descends, to water and refresh the earth. But although by this means sufficiently purified for every purpose for which it is designed, water in its natural state is never absolutely free from some foreign ingredients. Atmospheric water is the purest form in which this liquid exists; yet even this is usually found to contain some extraneous matter. According to the observations of Mr. Mallet, rain water, when fresh fallen, frequently contains one-fifth of its volume of oxygen; and Dr. Daubeny mentions that carbonic and muriatic acid, as well as various salts and earthy compounds, have been detected in rain water, besides a peculiar organic matter to which the name of *pyrrhine* has been given. Snow has been found to exhibit traces of muriatic acid and of an organic colouring matter, whilst in hail, ammoniacal salts have been observed; and dew has shown vestiges of nitric and muriatic acid. It is remarkable that in hoar frost no signs whatever of extraneous matter have hitherto been found. Besides the above-mentioned substances, iron, nickel, and manganese have been detected in minute quantities in atmospheric water; and it has been remarked that the first fall of rain brings to the ground, the same

foreign ingredients which are contained in the atmosphere of any particular locality where it may descend. We may, therefore, expect that rain or snow, falling on a remote and uninhabited mountain top, will be more pure than that collected in the vicinity of marshes, or of populous districts.

Since it appears that atmospheric water is not wholly free from extraneous matter, we shall readily suppose that spring water is by no means absolutely pure; and in fact, the water of springs usually abounds with various salts, as well as earthy and other ingredients.

Common spring water has been found to contain between four and five parts in a hundred of its bulk in gas, of which by far the largest proportion consists of carbonic acid gas, and the remainder of atmospheric air. Besides these gases, spring water contains various salts in greater or less proportion, according to circumstances, and to the nature of the beds or strata, in which they take their rise, or over which their course lies. The principal salts met with in spring water are muriate of soda, muriate of lime, sulphate of potassa, sulphate of lime or magnesia, carbonate of lime, and sometimes carbonate of soda. The saline contents of good spring water generally vary from a three-thousandth to a six-thousandth part of the whole. Springs of this description are termed *soft*, and answer well for culinary and other domestic purposes. When the solid ingredients exceed this ratio, the water becomes *hard*, and is less fitted for cooking or for dissolving soap, in proportion to the excess of extraneous matter it contains; and when this is in great abundance, it becomes wholly unfit for domestic use, and forms *mineral springs*.

The purity of water is an essential consideration in many processes of the arts, and it frequently is a matter of no small importance to the manufacturer, to be aware of the quality of the water he employs, according to the nature of the works in which he is engaged. Chemistry, and chemical analysis, here render him great assistance; for, by becoming acquainted with the peculiarities of the extraneous matter, contained in the water of the spring, or stream, by which his manufactory

is supplied, he may avoid much loss and disappointment. The admixture of earthy salts, of neutral salts, or of metallic salt, according to the preponderance of the one or the other, will, in many processes, not only alter the power of water as a solvent, but produce essential changes in certain substances when they are dissolved. Thus, water affects vegetable colouring matter by means of the salts which it contains; and it is therefore important that the dyer should be careful in his selection of water, and employ for some purposes that which is soft, clear, without smell, and does not curdle soap; whilst for others, hard water is preferable; the latter being especially adapted for dyeing red and other colours that require astringency. Pure soft water is also essential to the proper performance of the process of bleaching; for hard water (that is, the salts hard water contains) will decompose, and unite with the soap used in the process; and the oily earth thus formed, will adhere to the piece of goods, leaving a yellow stain difficult of removal.

The astringent properties possessed by hard water are not, however, without their use, rendering it available for many economical purposes. Our readers may probably have observed the effects of this astringency, when washing the hands with soap and hard water; it being this peculiar quality of the water that causes the skin to contract, and renders the hands liable to be chapped, more especially in cold weather. A similar contracting effect is produced by hard water on the fibres of vegetables; a property which is of great importance in bleaching linen; for, although in that process, soft water, as we have seen, is essential to render the linen beautifully white, hard water, nevertheless, performs a very important part; for soft water would leave the fibres lax; whereas the linen, by being thrown into hard water after its washing with soft water, acquires a peculiar firmness which adds much to its value. It is upon this principle that laundresses immerse muslins and cotton goods in pump water after washing.

"The fountain water's cold contracting wave," is also of peculiar utility in many manufactures. Thus, hard water alone

is applicable for the manufacture of starch. The hardest water is preferred by masons for mixing mortar. Hard water is also requisite for making gypsum into the substance called plaster of Paris; rain water not being applicable for this purpose. Hard water is also important in the manufacture of earthenware; and it is said that a peculiar sort of hard water, strongly impregnated with saline matter, is used in the porcelain manufacture in China, which, from its peculiar properties, is supposed to refine and improve the kaolin, or porcelain earth.

The choice of water is a matter of considerable importance with the brewer, for, in some instances, the different saline substances water contains tend to improve the beer, whilst in others they injure both its colour and its taste. And hence the same brewer with a similar supply of malt, cannot produce an equally good beer in all parts of the kingdom. Thus, the Derby malt, which is much used in Lancashire, is found to make better beer in that county than in Derbyshire; and it has been supposed that this difference is attributable to the carbonate and sulphate of lime contained in the Lancashire waters. The river Trent has long been celebrated for the excellence of the ale made from the water of that river; Burton, Nottingham, and the other towns situated on its banks, being noted for the superiority of their malt liquor; a circumstance which is considered to arise, in some degree at least, from the calcareous nature of the strata through which the course of the river Trent lies, and the consequent presence of carbonate and sulphate of lime in its waters.

For making bread, on the other hand, hard water is wholly unfit, for it is found to impede fermentation, and the bread is in consequence less wholesome. The purest and softest water, therefore, makes the best and lightest bread, and it accordingly becomes a matter of paramount importance, that bakers should be careful in the selection of the water they use.

The object in the culinary application of water, is either to soften the texture of animal and vegetable matter, or to extract from these substances some of the soluble parts, and present them in a liquid form. Pure soft water is far better adapted

for both these purposes than hard water; and for boiling meat, soft water is also preferable, as it is liable to be reddened and discoloured by the salts contained in hard water. But on the other hand, hard water is of singular use in dressing fish; and the well-known superiority of crimped cod arises from the use of hard water, which acts upon the substance in the same manner that it does, as we have already seen, on the vegetable fibre of the flax, and also on the human skin, that is, by causing contraction*.

In cooking vegetables, likewise, the choice of water is very important, owing to the different effects produced on their texture by hard and soft water. Thus, green vegetables and pulse, lose both their colour and their consistence, if boiled in soft water, whereas, if boiled in hard water, the colour is much better preserved, and the texture less altered. If, however, we wish water to act as a solvent, as for instance in making soup, and extracting the vegetable aroma, as well as the animal juices, the purest soft water will be by far the most suitable.

Similar instances might readily be multiplied; but those we have adduced will suffice to show, that attention to the disclosures of science may be of great utility, not only in arts and manufactures, but even in the most ordinary domestic concerns. It may be thought that some of these applications of scientific research refer to subjects of minor importance; and perhaps in some respects they are so: but we cannot regard them as wholly valueless, for we do think that in whatever we engage,—whether it be to prepare food for our table; to whiten or else impart colour to the materials for our garments; to fathom the depths of the ocean, or to raise our minds to the most abstract contemplations;—we do think that it should be our endeavour to accomplish our object in the best possible manner; to aim at perfection; not to suffer the

* The mode in which this is effected is very simple; the fish is merely cut in slices and placed in cold hard water for about an hour. It ought, however, to be boiled also in *hard* water, and in that case it will harden, curdle, preserve its whiteness, and possess a remarkable firmness of texture.

faculties and powers with which we have been endowed to slumber in apathy, but to employ them, as far as in us lies, in developing the good qualities of all that surrounds us. It is true, indeed, that, if followed with the view solely to our own gratification, almost every pursuit may be regarded as of minor importance; but if with the view to promoting the comfort or advantage of others, and the glory of the Creator, then let our occupations be what they may, so long as they are suitable to our station in society, we may thus become useful in our generation. And further, we shall find that Physical Science, or, in other terms, the Study of Nature, will throw a halo round our pursuits, and will exalt and give a new interest to the most ordinary occurrences of daily life. Nothing will appear insignificant; for in everything on which we bestow our attention, we shall be able to trace the constancy of the laws given to nature by nature's LORD; and in small as well as in great matters, we shall find continually increasing proofs that the whole universe, and every individual portion of it, belong to one grand connected plan, designed and guided by one All-wise and Almighty as well as All-bountiful Being.

Go! and list to the foaming sea,
Glorious in its monotony;
Go! and look at the star-lit scroll,
Which the high heavens to earth enroll;
Go! to the mountains, for they be
From and for eternity.

Ask them where is their Maker—where?
Every one shall answer, "Here!"
Would'st thou know more, the ocean's roar,
The starry sky, and the mountains high,
Will all reply——
"Wisdom, love, and power!"

CHAPTER III.

LIQUID NATURE OF WATER.—ITS COMPRESSIBILITY.—SPECIFIC GRAVITY OF WATER, AND OTHER SUBSTANCES.—TABLE OF SPECIFIC GRAVITIES.

In order that we may more fully comprehend the beautiful adaptation of the waters of the globe to the part they are designed to fulfil in the economy of nature, it will be desirable that we should form some acquaintance with the laws by which they are governed; an inquiry which will not only bring before our consideration the nature of this remarkable liquid, but will also afford a satisfactory explanation of many phenomena, either of continual occurrence in the natural world which surrounds us, or which may present themselves to our notice, in our own daily and more familiar use of this beautiful and highly important fluid.

Water belongs to a class of bodies which, as we well know, are termed *fluids*. Fluids are of two kinds, usually distinguished as *elastic* and *non-elastic*. Elastic fluids include atmospheric air, the various gases, and vapour. Non-elastic fluids comprise water, oil, spirit, quicksilver, &c. The terms elastic and non-elastic must, however, be received with some reservation, for, in fact, all fluids have some degree of elasticity; and perhaps the terms *expansive* and *non-expansive* may more correctly and more clearly indicate the different nature of the two descriptions of fluid.

Expansive or elastic fluids, are remarkable for their tendency to spread themselves or expand in all directions. Non-expansive, or non-elastic fluids, or *liquids*, on the other hand, have in their natural state, no tendency to enlarge their volume, or expand, without the application of heat. As an illustration of the difference between expansive and non-expansive fluids, let us suppose the following experiment to be made. We first procure an air-tight vessel, capable of

containing a pint of air, water, or any other fluid, but so constructed that it can be enlarged at pleasure to the dimensions of a quart, without the admission of any additional quantity of fluid. Having filled this vessel, whilst at its smallest dimensions, with atmospheric air, (which we are aware is an elastic fluid,) if we, without admitting any additional air, extend the vessel to its largest capacity, the enclosed air will instantaneously expand and completely fill the enlarged vessel, so that the portion of air which previously occupied the space of a pint, will now occupy that of a quart. And it will be readily supposed, that this expansion of the air will not be limited to that particular measure, but that the same phenomenon would take place, were we to enlarge the dimensions of the vessel so that it should contain a gallon. If, however, we were to repeat the experiment with water, which is a non-expansive fluid, we well know that the result would be quite different. The pint of water, instead of expanding to the dimensions of a quart, and filling every part of the vessel, would remain of precisely the same size as when it occupied the smaller vessel, and would not rise to a higher level than that at which it previously stood.

Water is very difficult of compression; a circumstance which gave rise to the assumption of its absolute incompressibility: but, in fact, all liquids are in some measure compressible; and it appears that the degree of compressibility of any uniform fluid (that is, any fluid which is of similar composition in all its parts,) varies as well with the temperature as with the density.

The erroneous opinion of the non-elasticity of water, arose from the extremely small degree to which the compressibility of this fluid can be carried, by any force which we can employ, compared with the effect which may be produced by the same force in compressing air. This erroneous opinion of the absolute incompressibility of water, was considered to be confirmed by an experiment made at Florence in the year *1650*. A quantity of pure water was introduced into a hollow sphere of gold, which was selected as the cleanest and most compact

The experiment was repeated some years afterwards in this country by Mr. Boyle, but with a sphere of pewter instead of gold. The blow of a wooden mallet beat the pewter globe flat, and the vessel being then pierced with the point of a small nail, the water immediately sprang up to the height of two or three feet. The cause of this jet of water was not at the time understood, and it was erroneously considered as a confirmation of the opinion of the incompressibility of water, whereas, in fact, the spouting forth of the water, although it showed that water was capable of sustaining an immense pressure without undergoing any sensible diminution of volume, proved that some contraction had taken place, for the water would not otherwise have been thus forcibly ejected.

Subsequent experiments by Canton, and yet more recently by Perkins, Oersted, and others, have fully established the compressibility of water, and assigned the amount of compression to which it is subject. The experiments made by Mr. Canton were very simple, but quite decisive. He observed the height at which rain water, previously well boiled to expel the air, stood in a glass tube exposed to the pressure of the atmosphere; this being considered as equal to fourteen pounds. Having removed the air from the tube, by means of an air pump, he then found that the water rose in the tube; a circumstance which proved that the weight of the air must

have compressed the water, and caused it to occupy a smaller space. The amount of compression was found to be one part in 22,000; certainly a very minute diminution in its volume; yet sufficient to prove that water does possess some degree of elasticity or compressibility: of such small amount, however, that in the application of this liquid to all practical purposes, it may be considered as incompressible, or incapable of being pressed or squeezed into a smaller space when confined by external pressure, than it occupies in its free state. The recent experiments of Professor Oersted, of Copenhagen, have confirmed those of Canton: for, according to Professor Oersted, "the true compressibility of water is about forty-six millionths," a result agreeing very closely with that of Canton's experiments. The professor also agrees with Mr. Canton, that the compressibility or elasticity of water is not so great in high temperatures as in lower.

The experiments made by Mr. Perkins on the compressibility of water were carried on in deep water, instead of under the pressure of the atmosphere, like those of Canton and Oersted. It had long been remarked, that when a bottle filled with fresh water, and tightly corked, was plunged to a great depth in the sea, on raising it again to the surface, the water in the bottle had acquired a salt taste: from whence it appeared, that the cork must have been forced in, whilst the bottle was under water, and that the sea-water had gained admission. With the view of ascertaining how far, under such circumstances, the cork was forced in, Mr. Perkins constructed an instrument, which consisted of a stout hollow cylinder of brass, water-tight, and furnished with a moveable rod at the top, passing through an aperture in the latter, made air-tight and water-tight. To the top of this piston-rod was appended a spring-ring, so arranged, as to remain fixed at any point to which the rod should be forced downwards into the cylinder, and which, therefore, would perform the part of an index, marking the change in bulk of the fresh water, and consequently, its compressibility. Having filled the cylinder with water, Mr. Perkins plunged the apparatus into the sea, and on its being withdrawn, the

index ring was found to stand eight inches high on the piston-rod. From this experiment, Mr. Perkins inferred that the rod had been forced eight inches into the water in the cylinder when at the greatest depth. The pressure of the superincumbent sea-water upon the piston-rod was estimated at about 1300 pounds; and Mr. Perkins calculated that the water had been compressed one twenty-seventh part of its bulk. According to some recent experiments made by Captain Smyth, a bottle, filled with fresh water and corked, had the cork forced in, at the depth of about 180 fathoms below the surface. In such a case, the fresh water is found to be replaced by salt water. Sometimes the cork is inverted, but has always been found to return to the neck of the bottle.

Although we may not have it in our power to make such experiments as these, and to emulate the philosopher in proving the exact amount of the compressibility of water, we may readily convince ourselves by actual observation of its elasticity, and therefore of its compressibility. This is displayed in the well-known and common play called "ducks and drakes." A stone being skilfully thrown in a nearly horizontal direction against a surface of water, the stone will be observed to rebound. Now, if water were wholly inelastic, the stone, however judiciously thrown, instead of rebounding, would fall as *dead flat* upon the water as upon a mass of moistened clay. Water, therefore, must possess some degree of elasticity. This may also be proved by yet more simple experiments. Thus, fat and butter are wholly inelastic; and if we throw a lump of fat or butter into a plate, neither of these substances will rebound: but if, with equal force, we pour water into the same plate, it will rebound or sparkle up from the plate. We may also prove, by another equally simple experiment, that, although water is more elastic than fat or butter, it is not so elastic as some other substances. Glass is a highly elastic substance; and we shall find, if we pour water from some little height into a glass vessel (a tumbler or wine-glass, for instance), if the latter be dry, the water will rebound briskly, and fly about in all directions. If, however, the glass vessel be partially filled

with water, and we then pour water from the same height and with equal force, we shall perceive, that although the water does still rebound to a certain extent, it is with considerably diminished violence: and this difference may be considered as indicating the different degrees of elasticity possessed by the two substances. It also proves, that although water is not so elastic as glass, it is not wholly inelastic. We may also add that in the latter experiment, the degree of elasticity possessed by water appears to vary with the temperature, this being greater at low than high temperatures: a result which coincides with the observations of Professor Oersted, on the compressibility of water at different temperatures.

Fluids, as well as all other bodies, possess *specific gravity*, or *have a tendency to press downwards:* and the more dense any substance is, the more forcible is this tendency. This tendency to press downwards, arises from that grand law of nature by which all things are held to the earth's surface. We have seen that the particles of water are held together by an attractive power called the attraction of cohesion: the law to which our attention is at present directed, and which is called *the attraction of gravitation*, is quite distinct from the former; the one acting at a distance, the other only when parts are in immediate contact; the one acting on all bodies, the other only on bodies bearing certain relations to each other.

Let us pause a moment to consider the nature of the law of gravitation. "Each particle of matter," observes Professor Airy, "attracts every other particle. That is, if there were a single body alone and at rest, then if a second body were brought near it, the first body would immediately begin to move towards the second body; just in the same manner, if a needle is at rest on a table, and if a magnet is brought near it, the needle will immediately begin to move towards the magnet, and we say that the magnet attracts the needle. But magnetic attraction belongs only to certain bodies; whereas the attraction of which we speak here, belongs to all bodies of every kind: metals, earths, fluids, and even the air, are equally sub-

ject to its influence. Nor is it confined to the terrestrial globe; the earth, in its turn, is attracted by the sun, and the beautiful order in which the whole solar system is maintained, is, by gravitation, this grand and universal law."

This power of attraction is in proportion to the mass of the body: that is to say, a large mass of matter has a much greater power of attraction than a smaller one. As the earth is by far the largest mass of matter in its immediate vicinity, so it necessarily follows that the inhabitants, and all things upon the earth's surface, will be attracted towards it. And since the earth is of a spherical, or nearly spherical form, and consequently the deepest part, and, therefore, the greatest mass, in a line from any point on the earth's surface, will be the centre of the earth: so we shall find that all bodies falling to the earth are drawn in a direction towards its centre; and thus, if we let a stone drop from our hand, it will take an exact and unerring course towards that point; perhaps, indeed, slightly modified by a small opposing force, which it is not necessary here to take into account.

If the inquiry be made, what has universal gravitation to do with our present subject? our reply is, much, very much; for it is this attractive power that holds the waters in their place on the surface of the globe. We have seen that the attraction of cohesion draws and unites the minute particles of water together, and causes them to form one liquid. The attraction of gravitation draws them individually and collectively downwards to the earth. Owing to the perfect mobility of the particles among one another, each particle is free to obey the attractive influence; and the ordinary and well-known circumstance of the flowing downwards of water, may be regarded as an evidence of its ready obedience to the universal law. And not only is the fall of water the result of gravitation, but the level surface it assumes is likewise dependent on the same law; for, (allowing other conditions to be similar,) owing to the perfect mobility of the particles of water, each particle, in any body of that liquid (unless impeded by some obstacle,) is able to move, so as to place itself at the same relative distance

from the earth's centre, as each other particle. And from hence it follows, that in all parts of the globe the waters of the ocean, when they possess a free communication, have the same general level—subject perhaps, however, to local variations arising from local causes, but sufficiently uniform for the *level of the sea* to be used as the standard, from whence the elevation of land is measured in all parts of the earth's surface. But although water maintains a general level, we must remember that, owing to the curvature of the earth, and to this very law of gravitation which attracts all things towards the earth's centre, no body of water will be perfectly *flat;* a remark which applies as well to small bodies of water as to the expanse of the ocean; though, in the former case, the deviation from the plane or even surface is so small, that it is not evident to our senses.

But what is the cause of this powerful and all-pervading attraction? The wisest philosopher can as little assign the *cause* as the simplest child. The only answer which can be made is, that it is a law given to nature by the all-wise and omnipotent Creator.

> As falls a sparrow to the ground,
> Obedient to His will,
> By the same law those globes wheel round,
> Each drawing each, yet still all found
> In one eternal system bound,
> One order to fulfil.

Various fanciful hypotheses have been suggested with a view to accounting for this remarkable power: and some writers have even gone so far as to attribute the mutual attraction of matter to a sort of kindred affection and harmony between the particles. But this is, in fact, only putting the effect for the cause; for the law of the attraction of gravitation does not arise from the harmony of nature, but is productive of that harmony. It is the bond of union of all nature; and if we seek for, and would find the evidence of love, it must not be in the particles of matter, but in that unseen but Almighty Being, who hath called these particles into existence, and who, with the happiness

in view, hath formed the whole universe, and imparted this wonderful power to matter. And although we may not be able to fathom the cause of this attraction—to ascertain why one mass should attract another—we shall not the less be struck with admiration at the beautiful adaptation of this law, to the government not only of the terrestrial globe, but of the whole universe.

Let it speak
The Maker's high magnificence, who built
So spacious, and his line stretched out so far,
That man may know he dwells not in his own;
An edifice too large for him to fill,
Lodged in a small partition, and the rest
Ordained for uses to his Lord best known.

To return to the subject of gravity. All bodies, as we have already seen, possess *specific gravity*, or *have a tendency to press downwards*. As this tendency to press downwards arises from the attraction of gravitation, all bodies resemble each other in this respect; and if the resistance of the air, and other opposing forces, were removed, large and small stones, lumps of lead, and even feathers, would fall the same number of inches in a second of time; but where there is any resistance, a large stone will press with much greater force than a small one. It is, in fact, this downward pressure which causes the feeling of weight in the hand, or the balancing downwards of a pair of scales; and it is the amount of this pressure which forms the weight or gravity of a body.

It further appears that where resistance is encountered, as, for instance, that of air, water, &c., every *species* of substance has a fixed degree of gravity, or tendency to press downwards, peculiar to itself: this is called its *specific* gravity, and is in such constant relation to the volume or bulk of the individual species, that when it is once known, we may rely upon this measure as a standard of the purity of the specimen. Thus, a square or cubic inch of pure gold, always weighs the same, or has the same specific gravity, as another cubic inch of the same metal if equally pure; but if mixed with an alloy of tin and copper, its weight would vary according to the pro-

portion in which these metals had been added; and in many cases, the adulteration of various substances has been detected by this test, which is therefore of great importance, not only in scientific researches, but also in a mercantile point of view.

Substances similar to those of whose genuineness we are desirous of making trial, cannot, however, always be procured, and very rarely, a mass of equal dimensions. Some other mode of ascertaining its specific gravity must therefore be adopted,—some other substance be fixed on, which can be conveniently procured, and which may serve the purpose of a standard weight; and in accomplishing this, we must compare its weight, with that of a fixed bulk of the substance whose specific gravity we are desirous of ascertaining. When we have once determined this, we shall at any future time, if we wish to repeat the trial, know what bulk of our standard weight will be equivalent to any particular bulk of the other substance. As a convenient general standard for this purpose, *pure* water, that is, either rain or distilled water, has been selected: this substance being of all substances, the least liable to change in its density; neither does it differ in any part of the globe; and it may also generally be readily procured; at least in all parts where such experiments are likely to be made. This, however, must be done at one fixed temperature, for the density of water varies with its temperature; and accordingly, that of 60° Fahrenheit has been chosen for this purpose, at which temperature water ranks as unity, or 1·000.

The mode originally adopted of obtaining the specific gravity of any substance, consisted in immersing the body in water, and accurately observing the amount of water displaced, and then weighing the latter against the substance whose specific gravity was required; water, as we have just seen, being considered as 1·000. In this mode of proceeding, if we immerse a mass of pure gold, of any given size, in water, we shall find that it weighs nineteen times and some fractions (or parts of a thousand) more than the water; its specific gravity is therefore thus expressed, 19·250. Gold in this state is, however, too soft and ductile for general purposes, and

accordingly, the standard coinage gold is alloyed with one-ninth part of copper, the specific gravity of which is less than that of gold, and thus it becomes harder and fitter for use, but its specific gravity is lowered to 18·000, that is to say, a sovereign, or other mass of standard gold, is eighteen times heavier than an equal bulk of water. Now, a sovereign ought to weigh 5 dwts. 3¼ grs.; and if a counterfeit coin were to be made of an alloy of tin and copper, but having its surface overlaid with a coating of gold of sufficient thickness completely to deceive the eye by its appearance, and even the ear by its sound, if rung; and if still further, in order to compensate for the lightness of the alloy, a little additional thickness were given it, so that it should possess the weight of a standard coin, and that by ordinary means, the imposture might scarcely be detected; yet, if the specific gravity of this counterfeit coin were taken, the deception would at once be evident; for, when compared bulk for bulk with water, its specific gravity would perhaps not much exceed 8·000. It is in this manner that the purity and consequent actual value of the precious metals can alone be ascertained.

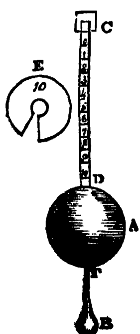
This method of obtaining the specific gravity of bodies, dates its origin from the time of Archimedes. Hiero, king of Syracuse, is said to have employed an artist to make a regal crown of gold, for which purpose the monarch furnished him with a sufficient quantity of that metal. When the crown was finished, its weight was found to equal that of the gold provided for it; but the king having reason to suspect that some adulteration had been practised, was very desirous of ascertaining the truth, and accordingly applied to Archimedes for the means of detecting the fraud, should any such have occurred. That philosopher could not for some time devise any means by which this could be effected, without injuring the crown. At length, however, a casual observation he made, suggested to him the means he might adopt to solve the question. As he was stepping into a bath, he noticed that the water rose in proportion to the bulk of such portions of his body as were successively immersed in the liquid; and reflecting on the circumstance, it occurred to him

that a body of equal bulk or size with himself, would raise the water in the same degree, though a body of equal weight, if of smaller size, would not; he at once applied this observation to the solution of the question respecting Hiero's crown, and sprang out of the bath, exclaiming, "I have discovered it! I have discovered it!" He then procured two masses of metal of equal weight with the crown, one formed of gold and the other of silver, and having filled a vessel with water, he plunged first the one and then the other mass of metal into the water, carefully noting in each instance the quantity of water that was displaced and flowed over. As he had anticipated, he perceived that the mass of silver displaced a larger quantity of water than the mass of gold, the specific gravity of silver, even when pure, not exceeding 10·474, whilst that of the mass of gold which Archimedes used on this occasion, may be supposed to have been about the same as our standard gold, or nearly 18·000. The philosopher then repeated the experiment with Hiero's crown, when he found, that although it displaced a smaller quantity than the mass of silver of equal weight, it displaced a larger quantity than the mass of gold. It thus became evident that Hiero's suspicions were not unfounded, and that in fact the gold of the crown had been adulterated; a result which that monarch could not otherwise have obtained without melting the crown.

This mode of determining the specific gravity of bodies is not, however, applicable in all cases, and instead of measuring the bulk of the body whose specific gravity is to be ascertained, it is usual to observe the loss of weight sustained by the solid, which is a more exact mode of proceeding; and the specific gravity of fluids is obtained, by weighing a certain portion of the fluid in a bottle, against an exactly similar bulk of water. Thus, a phial containing 1000 grains of distilled water, would hold 13,598 grains of mercury, and not more than 792 grains of pure alcohol; and accordingly we find that the specific gravity of water being 1·000, that of mercury is 13·598, or rather more than thirteen and a half times as much as water, whilst that of alcohol is only 0·792 or 792 parts of a thousand.

Or to express the same thing in other terms, a cubic foot of water weighs 1000 ounces, and consequently a cubic foot of mercury would weigh 13,598 ounces, and a cubic foot of alcohol 792 ounces.

In chemistry and mineralogy a knowledge of the specific gravity of bodies is essential, for the purpose of proving the purity, and even in some cases the identity, of various substances. Thus, the mineral called the *cubic sulphuret of iron*, and that called *crystallized bright cobalt*, are so nearly similar in appearance that the nicest eye cannot distinguish them with certainty; but the specific gravity of the first invariably ranges between 4·600 and 4·800, and that of the latter between 6·300 and 6·500; so that if tried by this test the one cannot be mistaken for the other. The strength and purity of spirits, and of the acids, as also of various solutions and infusions, can be ascertained solely by obtaining their specific gravities. Sulphuric acid, for instance, is capable of being adulterated in such a manner that, without any material alteration in appearance, it may vary considerably in strength; but its specific gravity, when pure, is 1·840, and if tested in this way any adulteration may be readily detected.



The specific gravities of fluids are most usually obtained by means of a *hydrometer*. There are various forms of the instrument so called, but the hydrometer in most general use in this country is Sykes' hydrometer, of which a representation is here given. This consists of a thin brass stem, D, about six inches in length, passing through and soldered into a hollow ball, A, of the same material, about an inch and a half in diameter. The stem extends about an inch below this hollow ball, and to the inferior or lower extremity of this portion of the stem is fixed permanently a pear-shaped weight, B (other weights being provided if required for denser liquids.) The use of the hollow ball is to cause the instrument to float, so that, when immersed in any liquid

the upper extremity of the brass stem will rise perpendicularly above the surface, and on this portion of the stem is marked a scale of degrees. The instrument will of course sink in proportion to the weight attached, which must be regulated by the observer, according to the known specific gravity of the liquid which is to be tested. And, since the weight of the fluid displaced by the ball, or any floating body of known size, is *constant*, or, in other terms, not subject to vary, it follows that, if the liquid on which the experiment is made be pure, the instrument will invariably sink to a certain depth, which will be indicated by the scale of degrees on the upper portion of the brass stem. This hydrometer is employed in proving spirits for the collection of the spirit revenue of Great Britain. No spirit is allowed to be sold for the purpose of drinking which is above *proof.* "Proof spirit" consists of half water and half pure spirit; and in the ordinary use of this instrument for commercial purposes, the specific gravity of spirits refers to this standard, and not to that adopted by science. Pure alcohol, as we have seen, is lighter than water; and if spirits offered for sale contain an undue proportion of the former, the specific gravity of the spirits will not be so great as that required in proof spirit, and the instrument will sink deeper in the liquid. Thus, if the liquid contains twenty parts in a hundred more pure alcohol than proof spirit is allowed to contain, the hydrometer will sink so as to indicate twenty above that standard, and the liquid must therefore be lowered by the addition of a due proportion of water before it may be offered for sale. The specific gravity of spirits, however, varies greatly with the temperature, and, consequently, at different seasons of the year. This difference must, therefore, be taken into consideration, and accordingly a thermometer always forms part of the hydrometrical apparatus.

The specific gravity of cow's milk is 1·030; and if water should be mixed with it, this may readily be detected by means of the hydrometer. In some parts of Switzerland and of the north of Italy, the peasants, many of whom possess a single cow, daily carry the milk to large cheese-farms in their

neighbourhood, receiving at the end of the year an equivalent portion of cheese. At these farms, in order to ascertain the good quality of the milk, hydrometers are used; for, since water is specifically lighter than milk, any admixture of the former would immediately be detected by the use of that instrument.

Oil is specifically lighter than water, the specific gravity of olive oil being 0·915. If placed upon water it will therefore float on its surface. The same remark applies to naphtha, or liquid bitumen, the specific gravity of which does not exceed 0·847; and this circumstance renders it so buoyant, that this inflammable substance will burn freely on the surface of water.

Air is about 820 times lighter than water; if free it therefore naturally retains a position above water. Air, and other gases, notwithstanding their expansive power, are not without their gravity, or weight, and consequently they have a tendency to press downwards; and this pressure or weight of the air exercises considerable influence on all substances upon the earth's surface. A column of air covering an inch square, and considered as extending to the boundary of the earth's atmosphere, is estimated as equivalent to fourteen pounds and a half. This is termed the *weight of an atmosphere.*

We have seen that the specific gravity of water is reckoned as unity, or 1·000, and that a cubic foot of this liquid weighs 1000 ounces. This, however, it must be remembered, applies only to distilled, or pure rain water, at the particular temperature of 60° Fahrenheit: for we have already seen that the density, and consequently the specific gravity of water, increases with a diminution of temperature, until we arrive at that of about 39°; and the waters of springs, rivers, and lakes, being usually more or less impregnated with extraneous substances, their specific gravity will be augmented, and liable to vary according to circumstances. The specific gravity of the waters of the ocean is greater than that of most springs, rivers, and lakes, but it is more uniform in its density, sea-water being found to have nearly the same specific gravity in all parts of the globe: the increase in the specific gravity of sea

water above that of pure water being about twenty-six or twenty-eight parts in a thousand; so that the specific gravity of the waters of the ocean ranges from 1·026 to 1·028. A cubic foot of sea water would therefore weigh about 1027 ounces; and, consequently, distilled or rain water, or, indeed, any kind of fresh water, being specifically lighter than sea-water, would naturally, if undisturbed, float on the surface of the latter; a circumstance which is of frequent occurrence near the mouths of large rivers which enter the sea. Of this the river Amazonas, or Marañon, perhaps affords one of the most striking examples, the surface of the ocean being found still to retain its freshness at the distance of 300 miles from the embouchure of the river, and not till then, have the winds and the waves of the mighty Atlantic, power to unite it wholly with the general mass.

One advantage arising from the circumstance of fresh water being specifically lighter than sea water, and consequently maintaining its position at the surface, near the mouths of rivers, is too remarkable and too important to be passed unnoticed. We allude to the opportunity thus in some cases afforded to navigators of obtaining supplies of fresh water from the upper stratum. The phenomenon is very strikingly displayed in the Santa Cruz, a river of Patagonia; and may perhaps be considered as indicative of the purity of its waters, the sea water being observed to flow into the mouth of that river in an under current. And "in dipping any thing into the stream for fresh water," observes Captain Fitzroy, "it is advisable not to dip deep, or to let the hose (if one be used) go many inches below the surface, since it often happens that the upper water is quite fresh, whilst that underneath is salt."

This difference in the specific gravity of fresh and sea water is not without its importance in the construction of boats and other vessels. Every substance that is lighter, or has less specific gravity than water, floats upon its surface, and while so doing, sinks to a certain depth, or in other terms, displaces a certain quantity of the fluid, exactly equal to its own relative weight or gravity, and a balance is thus produced between the

body and the fluid on which it floats, a fact which may be regarded as constituting one of the leading and most important principles in hydrostatics. Now, a boat floating on *sea water*, will sink to a certain depth in the water; but if the self-same boat be employed in navigating a *fresh water* lake, or a river, it will sink to a greater depth, owing to the lesser degree of specific gravity in the latter; in consequence of which, a larger quantity of the water will be displaced to equal the weight of the boat; that is, the boat will sink deeper in fresh water than in sea water; and accordingly, a boat intended for sea use may be made more solid, and will bear heavier burdens, than one designed for use in fresh-water streams or lakes.

All bodies that are heavier than water will of course sink in the fluid, because, since their bulk is smaller in proportion to their weight, they do not displace a sufficient portion of the water to balance their weight, but only a quantity equal to their own bulk. And hence, all bodies that are lighter, or have less specific gravity than water—as, for instance, a deal board—will float at the surface, having a greater or less portion of its mass immersed, according to its relative specific gravity to that of the water on which it floats. A body that is heavier than water, such as a mass of gold, will of course sink to the bottom; unless, indeed, the greater degree of specific gravity be compensated by placing it on some lighter material, having a more extended surface, such as a raft formed of deal boards, or a hollow vessel, which, by its greater bulk, will displace a larger portion of water than is equal both to its own weight, and to that of the mass of gold. A solid block of oak timber is heavier than water, but if scooped out, its relative bulk will be greater than its relative gravity, and it will then not only float at the surface, but may also be sufficienily buoyant to bear some additional burden. This principle is acted upon in the construction of ships and floating vessels of every description; and it is on this principle that the brass ball of the hydrometer floats in the liquid to be tested: and that even iron sea-vessels may be constructed.

A ship designed to carry 500, or any other number of tons burden, must be so constructed as to displace a certain proportion of water, exactly suited to maintain its balance in the water; for, if too light, it will not be well poised, and not ride steadily on the water; and if its weight should be too great for its bulk, it will sink too low beneath the surface of the water, and the risk will be incurred of the water's entering the vessel. And thus, a ship designed to carry coals, the specific gravity of which varies from 1·020 to 1·300, would require to be of very different construction from one which was to be laden with iron, the specific gravity of which is about 7·788; and, indeed, a vessel could not advantageously carry an equal *bulk* of iron and of coals, but only an equal *weight* of either substance. It is, however, in this way that the form and tonnage of vessels is regulated, according to the purposes for which they are intended; and trading ships, which are designed to carry large cargoes, are more bulky in their form, than such as are designed solely for carrying passengers, or for ships of war. Vessels of the former class, when their cargo is discharged, become too buoyant to be readily managed; and accordingly, when vessels convey a cargo to any port, and do not, after discharging it, receive in return, any cargo, or not any of equivalent weight, it is customary to take in ballast, that is, shingles, or any substance which can be procured free of expense, and to discharge this ballast when they reach their own port. This is very commonly done by the coal ships from Newcastle, and the consequent accumulation of the discharged ballast at the entrance of the river Tyne is said to be forming a mound which threatens to impede the access to that river. The more elegant form of ships of war than of merchantmen, and also that of pleasure-boats than of fishing-vessels, has its origin in this principle; and among modern improvements in naval architecture, an attention to this line of hydrostatics, and its influence on floating bodies, stands very prominent.

The earliest ships in the British navy (which may be considered as dating its commencement from the reign of Henry VII.) were high, unwieldy and narrow; their guns were

close to the water, and they had lofty poops and prows, like Chinese junks; they were, therefore, unmanageable, and far from safe. And it is mentioned, that on one occasion "the Mary Rose, a goodly ship of the largest size, by a little sway of the ship in casting about, her ports being within sixteen inches of the water, sunk." This took place at Spithead in the presence of the king, (Henry VIII.,) and most of her officers and crew were drowned.

It is to the same hydrostatic principle that Dante refers in *L'Inferno*, when, in describing his transit across the Stygian Lake, under the guidance of the poet Virgil, he alludes to the circumstance of the bark of Charon sinking more deeply in the waters of the "livid lake," when bearing its unusual freight of a human body, than when passing with its ordinary cargo of disembodied spirits.

Nor till my entrance, seemed
The vessel freighted. Soon as both embarked,
Cutting the waves, goes on the ancient prow
*More deeply than with others it is wont**.

Owing to the difference of their relative specific gravities, some species of timber float, whilst others, being heavier than water, sink to a greater or less depth in that liquid; dependent, of course, on the greater or less density of the water. Ash, beech, elm, and fir timber, being specifically lighter than water, will float at the surface; but some of the harder woods, such as British oak, box-wood, mahogany, ebony, Indian cedar, &c., being specifically heavier than water, will not float. This hydrostatic fact is practically displayed in a remarkable manner in the island of Ceylon, the interior of which abounds with dense forests, containing a great variety of timber trees. The mode adopted by the inhabitants of those districts for conveying the timber to the coast districts, consists in floating it down the rivers; and as the light and

* E sol quand' io fui dentro parve carca;
Tosto ch'l duca, ed io nel legno fui,
Segando se ne va l'antica prora,
Dell'acqua pui che non suol con altrui.
Inferno, Canto 8.

less valuable timber alone is capable of floating, the consequence is, that such are alone brought down, whilst the heavier and more valuable woods, such as ebony, satin wood, iron wood, &c., being too heavy to float, are left to perish on the spot which bears them.

But in fact, the inferior or lesser gravity of wood of almost every kind, compared with that of water, is owing to the interstices of the wood being filled with air, and if these should become occupied by water instead of by air, the whole mass would be heavier than water, and accordingly sink to the bottom. This is termed being *water-logged*. Mr. Scoresby mentions a singular instance of a boat becoming thus water-logged, under the pressure of the sea at a great depth, by which its specific gravity was remarkably increased. This occurred during a whaling expedition in the Arctic Regions. "On the 31st of May, the chief mate of the Henrietta, of Whitby, (the ship Captain Scoresby then commanded), struck a whale, which ran out all the lines out of the boat before assistance arrived, and then dragged the boat under water, the men meanwhile escaping to a piece of ice. When the fish returned to the surface to 'blow,' it was struck a second time, and soon afterwards killed. The moment it expired, it began to sink, which not being a usual circumstance, excited some surprise. Captain Scoresby, who was himself assisting at the capture, observing the circumstance, seized a grapnel, fastened a rope to it, threw it over the tail of the fish, and fortunately hooked it. It continued to sink, but the line being held fast in the boat, at length stopped it, though not till the 'strain' was such, that the boat was in danger of sinking. The fish being relieved from the weight of the lines and sunken boat, rose to the surface; and the strain was transferred to the boat connected with the disengaged harpoon. Captain Scoresby, imagining that the sunken boat was entangled among rocks at the bottom of the sea, and that the action of a current produced the extraordinary stress, proceeded himself to assist in hauling up the boat. The strain upon the line he estimated at not less than three-fourths of a ton,

the utmost power of twenty-five men being requisite to overcome the weight. The laborious work of hauling the line in, occupied several hours, the weight continuing nearly the same throughout. The sunken boat, which, before the accident, would have been buoyant, even though full of water, now when it came to the surface, required a boat at each end to keep it from sinking. When it was hoisted into the ship, the paint came off the wood in large sheets, and the planks, which were of wainscot, were as completely soaked in every pore, as if they had lain at the bottom of the sea since the Flood! A wooden apparatus that accompanied the boat in its progress through the deep, consisting chiefly of a piece of thick deal, fifteen inches square, happened to fall overboard; and though it originally consisted of the lightest fir, sunk in the water like a stone. The boat was rendered useless; even the wood of which it was built, on being offered to the cook as fuel, was tried and rejected as incombustible."

The effect produced in the above singular instance, did not, however, as will be observed, arise from simple immersion in sea water, but from immersion under great pressure by the super-incumbent waters of the ocean; this being equal, at the depth of 4000 feet, to about eighteen hundred weight on every square inch of surface.

It is on the same prolific hydrostatic principle of specific gravity that life preservers to guard against accidents in water are constructed. One of the simplest and best machines for this purpose is made in the form of a broad belt or girdle to encircle the person of the wearer. It is composed of two folds of water-proof leather or caoutchouc; these two folds being united so as to be perfectly impervious to water, and having a small stop-cock in front. This machine is fastened firmly to the body of the wearer, and when in its collapsed state, it forms only a flat girdle. When required for use, the bag or sac, formed by the two folds of water-proof stuff, is to be inflated by blowing into it with the breath, through the aperture at the stop-cock; and when this is properly filled, the cock is turned so as to prevent the escape of the air. The

sac being now distended, is able, by its increased bulk, and consequent buoyancy, not only to sustain the wearer himself, but sometimes an additional weight. The utility of this machine has been proved on many occasions; and an instance is recorded of four persons, two ladies and two gentlemen, having been saved from drowning by this means in Braydon Water, between Yarmouth and Norwich. The party set out in a pleasure-boat, with the design of proceeding by water to Norwich, and one of the gentlemen had taken a life-preserver on board, rather, however, with the view of displaying the nature of the machine, than as a safeguard in case of accident, or of its proving of real practical utility. They had scarcely entered Braydon Water, which, in some parts, is nearly two miles wide, ere a sudden gust overset the boat, and plunged the whole party into the water. The possessor of the life-preserver having inflated the sac, hastened to the relief of his companions, who were in the greatest peril, but, owing to the buoyoncy of the machine, the whole party were sustained from sinking, and were in this state driven by the current on Burgh Marshes, where their boat had already been cast on shore, and where they were happily able to obtain assistance, and the refreshment they so greatly needed.

Not very dissimilar from the life-preserver is the air-bladder in fishes, which, indeed, may be regarded as a most important hydrostatic contrivance, designed to vary the specific gravity of the animal's body, according to circumstances; these air-bladders being capable of being dilated and compressed at pleasure. When the air-bladders are dilated and filled with air, the specific gravity of the fish is lessened, and the animal being lighter than water, naturally ascends; when, on the other hand, the air is withdrawn, and the bladder compressed, the body of the fish being heavier than water, it sinks in that liquid; and the animal may regulate the greater or less degree of compression or of dilatation of the bladder, according to the greater or less depth beneath the surface to which its wants or inclinations may lead it.

The hydrostatic apparatus of the nautilus is even more

remarkable. The shell of this mollusc is *camerated* or *chambered*, that is, it is divided into compartments or cells. These chambers or cells are filled with air, and appear to be nicely adjusted on hydrostatic principles, so as exactly to balance the weight of the animal; and as the nautilus increases in size, and consequently in weight, a fresh chamber is added, each new chamber being of larger dimensions than the preceding. Nor is this the only hydrostatic apparatus possessed by the nautilus. A membraneous tube, called the siphuncle or siphon, traverses the chambered portion of the shell, apparently connecting the chambers with the body of the animal. Into this siphon the nautilus appears to have the power of injecting a liquid, and of withdrawing it at pleasure; and if the tube be filled with a liquid of equal weight with water, the whole mass becomes specifically heavier than water, and the animal sinks. When, however, the liquid is withdrawn, the balance is reversed, and the animal rises to the surface. "These beautiful arrangements are, and ever have been," observes Dr. Buckland, "subservient to one common object, viz., the construction of hydraulic instruments of essential importance, in the economy of creatures destined to move sometimes at the bottom of the sea, and at other times upon or near the surface of the sea. The delicate adjustments," (continues this eminent geologist, speaking of the fossil remains of the same family, as compared with the existing nautili,) "the delicate adjustments whereby the same principle is extended through so many grades and modifications of the same type, show the uniform and constant agency of some controlling intelligence: and in searching for the origin of so much method and regularity amidst variety, the mind can only rest when it has passed through the subordinate series of second causes, to that Great First Cause, which is found in the will and power of a common Creator."

TABLE OF SPECIFIC GRAVITIES.

SOLIDS.

Water, at the temperature of 60° Fahrenheit, ranking as 1·000.

Iridium	23·000
Platinum, in plates	22·069
Ditto, forged	20·336
Gold, hammered	19·361
Gold, cast	19·258
Tungsten	17·400
Mercury, solid *	15·610
Mercury, liquid	13·598
Palladium	11·800
Lead	11·352
Rhodium	11·000
Silver, hammered	10·510
Silver, cast	10·474
Bismuth	9·880
Uranium	9·000
Copper	8·900
Nickel, forged	8·666
Molybdenum	8·611
Cadmium	8·600
Manganese	8·000
Steel, hardened	7·840
Steel, soft	7·833
Iron, bar	7·888
Iron, cast	7·248
Cobalt	7·600
Tin	7·291
Zinc	6·861
Antimony	6·702
Tellurium	6·115
Chromium	5·900
Arsenic	5·763
Columbium	5·600
Ruby, oriental	4·283
Garnet, precious	4·230
Garnet, common	3·600
Sapphire, oriental	4·200
Sapphire, Brazilian	3·130
Topaz, oriental	4·061
Malachite	3·994
Beryl, oriental	3·549
Beryl, occidental	2·723
Diamond, oriental	3·531
Diamond, Brazilian	3·444
Amethyst, oriental	3·391
Amethyst, common	2·750
Fluor spar	3·791
Tourmaline	3·361
Limestone, compact, about	3·000
Glass, flint	3·000
Glass, plate	2·760
Glass, crown	2·520
Turquoise, about	3·000
Granite, about	2·950
Mica, about	2·930
Coral, red, about	2·850
Coral, white	2·570
Marble, Parian	2·837
Onyx	2·816
Emerald	2·770
Pearls, oriental	2·750
Felspar	2·700
Rock-crystal	2·650
Chalcedony	2·650
Carnelian	2·613
Agate	2·590
Portland stone	2·496
Plumbago or Graphite, from 1·987 to	2·400
Porcelain, from China	2·384
Porcelain, Sevres	2·145
Ultramarine	2·362
Opal, precious	2·114
Slate, drawing	2·110
Oyster-shell	2·092
Sulphur, native	2·033
Nitre	1·900
Alabaster	1·874
Ivory	1·825
Anthracite	1·800
Alum	1·714
Sugar	1·606
Gum-arabic	1·452
Honey	1·450
Lignum vitæ	1·333
Ebony, American	1·331
Ebony, Indian	1·209
Peat, compact	1·329
Coals, from 1·020 to	1·300
Jet	1·300
Oak-heart, 60 years old	1·170
Amber from 1·064 to	1·100
Mahogany	1·063
Brazil wood	1·031
Indigo	1·009
WATER	1·000
Camphor	0·988
Sodium	0·972

* That is, at the temperature of 3° below Zero, on Fahrenheit's scale.

Wax, bees'	0·964
Lard	0·947
Spermaceti	0·943
Butter	0·942
Tallow	0·941
Fat, pork	0·936
Fat, veal	0·934
Fat, beef	0·923
Fat, mutton	0·923
Caoutchouc	0·933
Ice	0·930
Ambergris from 0·780 to	0·926
Potassium	0·865
Beech timber	0·852
Ash	0·845
Yew, Spanish	0·807
Yew, Dutch	0·788
Alder	0·800
Apple-tree	0·793
Deal, yellow	0·657
Cypress, Spanish	0·644
Cedar	0·613
Linden or Lime	0·604
Fir	0·550
Poplar	0·529
Poplar, common	0·383
Cork	0·240

LIQUIDS.

Sulphuric acid	1·840
Nitrous acid	1·550
Water of Dead Sea	1·240
Nitric acid	1·217
Constantia wine	1·081
Vinegar	1·080
Oil of cinnamon	1·043
Oil of cloves	1·036
Milk	1·030
Sea water, about	1·026
Malaga wine	1·022
Cyder	1·018
WATER	1·000
Port wine	0·997
Burgundy wine	0·991
Linseed oil	0·940
Proof spirit	0·923
Oil, whale	0·923
Oil, olive	0·915
Ether, nitric	0·908
Ether, muriatic	0·874
Naphtha from 0·700 to	0.847
Alcohol, pure	0·797
Atmospheric air	0·001¼

GASES.

Atmospheric Air reckoned as Unity, or 1·000.

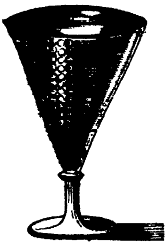
Hydriodic acid (the heaviest gas known)	4·340
Nitrous acid	2·638
Chlorine	2·500
Sulphurous acid	2·222
Carbonic acid	1·527
Muriatic acid	1·284
Oxygen	1·111
ATMOSPHERIC AIR	1·000
Carbonic acid gas	0·972
Carburetted hydrogen	0·972
Nitrogen	0·972
Prussic acid	0·937
Vapour of water	0·623
Ammoniacal gas	0·590
Hydrogen	0·069

CHAPTER IV.

HYDROSTATICS.—EQUILIBRIUM OF WATER.

We have already seen that the parts of water and other fluids, are perfectly moveable among one another by the slightest partial pressure. This perfect mobility of the parts gives rise to the *equilibrium of fluids*, or, their *equal pressure in all directions*, which may be considered as the fundamental truth on which all the laws of HYDROSTATICS depend. Few and simple as these principles may appear, they nevertheless give rise to a train of curious and important results, scarcely yielding to those deducible from any other branch of science, either in the interesting views they unfold of natural phenomena, or in their practical utility to man.

We have just stated that it is a fundamental truth that water presses equally in all directions: let us not, however, be misunderstood. If we put water in a square open cistern or vessel of any kind, it does not, while at rest, press with equal force above, below, and laterally: the very circumstance that detains it in its liquid form—its natural want of expansibility—prevents it from pressing upwards; besides which, there are certain forces perpetually acting upon it, and giving it a tendency to press in a contrary direction: both the attraction of gravitation and its own gravity cause it to press downwards, whilst the weight of the atmosphere, which we have seen is equal to 14½ lbs. on every square inch, lends its aid in pressing it in the same direction. From what has just been said of this downward pressure, we shall be led to expect that the pressure of the water on the bottom of the cistern will be greater than that on the sides. Nor shall we be mistaken in this conclusion; for, if we suppose our cistern or vessel to be square, and capable of containing a cubic foot of water, the pressure on the bottom will be equal to a force of 1000 ounces, whilst that on each side of the cistern will not be equal to more than half that on the bottom—or 500 ounces. But when we consider the lateral pressure, or the pressure on the sides, then, indeed, we



If the vessel, instead of being square, were to be of the form of an inverted cone, like that represented in the accompanying diagram, the force of the downward pressure would vary in the different parts of the vessel, according to the depth of the water; and in describing the phenomena of this fluid, it is common to assume that its minute particles are arranged in a linear vertical direction, as though water consisted of a vast number of minute columns, each having a direction, in accordance with the laws of gravitation, towards the earth's centre. The weight or pressure of these supposed columns varies with their height; for we need scarcely remind the reader that a column or vertical line of marbles or of cannon-balls, containing fifty, would weigh more than one containing half that number.

The increase of pressure which thus takes place in proportion to the depth of the fluid, renders it important in the construction of tanks and reservoirs designed for holding water, to make them of strength proportionate to the depth of the liquid they are intended to contain. In constructing large tanks and reservoirs, this, indeed, forms no trifling consideration, it being a superfluous expense to make them equally thick and strong throughout the whole depth; for, if they are thick enough to bear the great pressure in the lower part, they will be stronger

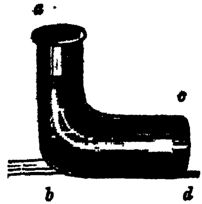
than is required for the pressure in the upper part. The same remark applies to flood-gates, banks, and dykes. If, therefore, a tank or vessel have the same diameter through the whole of its depth, the walls or sides must, in order to render it secure, gradually increase in thickness from the top to the bottom; and care must be taken to ascertain that the thickness of the sides at the greatest depth, is sufficient to resist the pressure in that part of the tank. This may be ascertained with great precision, the regular proportion having been determined by mathematical reasoning, and it is found, in some measure, to depend on the specific gravity of the material of which the sides of the tank may be formed; and to differ, according to its specific gravity, compared with that of the water it is to contain. Thus, if a bank be formed of common stone, the specific gravity of which is about twice that of water, the thickness of the wall at the base ought, in order to resist the pressure, to be equal to half the height—that is to say, if the water stand six feet high in the tank, there ought to be three feet thickness of solid masonry in the walls, at the bottom. If the wall or bank be formed of fir timber, which is not much more than half the weight of water, it would not bear a similar pressure; and either the wall must be thicker at its base, or the water not so deep.

We are, however, so accustomed to consider weight as a certain quality possessed by particular substances, and which renders them *heavy*, that we are apt to forget these are mere conventional terms, adopted as a convenient mode of expressing the fact of their downward pressure, by no means explanatory of the laws on which this downward pressure depends; but rather, on the contrary, calculated to lead us to suppose that they possess actual heaviness. A simple experiment will, however, prove that when any substance weighs or presses down the scale, this does not arise from this supposed actual heaviness, but from the tendency all bodies have to press downwards. Being provided with a pair of scales, let us place a jar or tumbler, containing a certain quantity of water (suppose eight ounces,) in the one scale, and corresponding weights

But although water, when in an open tank, cistern, or vessel of any kind, presses with greater force in a downward than in a lateral direction, and does not press upwards when unconfined, we shall find that when it is confined in a close boiler, or vessel of any kind, and acted on by any force, whether by the expansive power of heat, or by any other that may be applied, water *presses equally in all directions;* above, below, and laterally—a law of hydrostatics which leads to results equally remarkable and important.

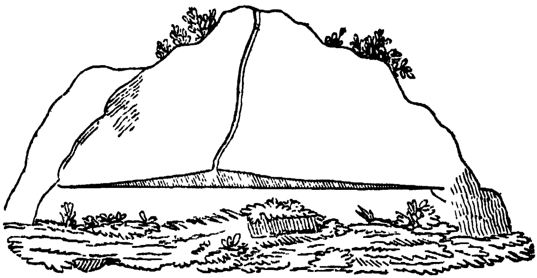
We have just seen (and there is certainly nothing that appears extraordinary in the circumstance) that a column or vertical line of water containing fifty, or fifty thousand, of the minute particles of that liquid, will press downwards with greater force than a column containing half as many; we might therefore perhaps expect, as a matter of course, that if water were placed in a vessel of the form represented in the accompanying diagram, the height of the water being, as will be observed, greater in the portion of the vessel extending from *a*

to *b*, than in that extending from *c* to *d*, we might expect the water would press from *a* to *b* with greater force than from *c* to *d*, equivalent to the greater height of the column of water in that portion of the vessel. Such, however, is not the case, the pressure being, in fact, equal in all parts of the bottom of the vessel. This statement may at first appear not a little startling, and at variance with what has already been said respecting the greater pressure of a longer column or body of water; and indeed, from its apparent incongruity, this principle has been called the *hydrostatic paradox*. There is, however, no difficulty attending the explanation of this phenomenon, which arises from the perfect mobility of the parts of water, and only forms an instance of the hydrostatic principle of the equal pressure of fluids in all directions. The water, in the first place, flows freely downwards and laterally until it has filled the vessel. In the inclosed portion, *b c*, it, however, encounters resistance to its further progress, from the sides and upper surface of the vessel: checked in its onward course, and imprisoned within certain limits, and being, from the mobility of its parts, ready to yield to any partial pressure, the whole body of water in the vessel becomes pressed downwards by any force which may be exerted at *a*, and, owing to the resistance it encounters from the top of the vessel at *c*, with equal force in every part; the degree of force being dependent on the amount of pressure at *a*, and on the height of the water from *a* to *b*. In a vessel having an aperture an inch square at *a*, the ordinary pressure of the atmosphere would be equal to 14¼ lbs., and this pressure would act in all directions in the horizontal limb of the vessel, above, below, and laterally. If the pressure be increased, the water in the vessel will press with greater force in every direction, and if the pressure be augmented to a great amount, the vessel may burst, and be rent asunder with great violence.



The effects produced by this hydrostatic principle of the equal pressure of water in all directions, when confined within

fixed limits, conjointly with that of the pressure produced by a column of water of considerable vertical height, sometimes gives rise to exceedingly alarming phenomena in the natural world. To illustrate this observation, let us suppose a cavity to exist in the interior of a hill, or mountain, as represented in the accompanying diagram.



Internal Reservoir.

This cavity we will further suppose, though perhaps not exceeding an inch in depth, to form an area of 30 feet square, and to be filled with water, being fed by a small crevice or fissure, through which the water finds its way into this reservoir. An unusually heavy fall of rain takes place, and the water forcing its way down the crevice enlarges it to the diameter of an inch square, its whole length from the surface to the reservoir being 200 feet. The surrounding country being flooded, the crevice becomes completely filled with water, thus forming a column of water 200 feet in height, which, in accordance with the principles just alluded to, causes equal pressure of the water on all sides of the internal cavity with all the power due to a perpendicular column 200 feet in height. The water consequently will press with great force in every direction, and in all probability the mountain may be rent asunder with great violence, for it would be blown up with force equal to the pressure of 5000 tons of water, although, in fact, not more than two tons and a half would have been applied. Such accumulations of water in the interior of the earth may not unfre-

quently cause the disruption or rending asunder of rocks, thus giving rise to local earthquakes, and other phenomena. Nor is it impossible that to some such cause may be attributable, the shocks and detonations frequently noticed by travellers in some of the mountainous districts of the New World, especially in Guiana. By such a rending asunder of hills and mountains, the rocks would also, probably, be shattered into fragments of all dimensions; and in this way, as well as in many others, water may lend its aid in causing great changes in the earth's crust. And it is not impossible that the remarkable heap of fragments of rocks mentioned by Mr. Schomburghk as occurring in the Parima Mountains in British Guiana (where, as we have just seen, shocks and detonations are frequently heard, and where that eminent traveller observed thousands of rocks lying heaped in the greatest confusion, varying in size from immense blocks to that of an egg,) may originate in such a phenomenon. In other regions, as for instance in the basin of the Missouri, these fragments may have been borne onwards, and rounded by the action of water, thus forming those masses of rock, which are termed by geologists erratic blocks, or boulders.

We thus find that owing to the law of equal pressure, the force exerted by water and other fluids does not appear to be regulated by the quantity, or the weight of the fluid, but by the vertical height of a limited portion, and the area of the remaining portion on which it acts. In a practical point of view, this law is remarkable for the directness of its application to useful purposes; more particularly because the immediate and perfect distribution through the whole mass, of a pressure, applied to any one part, however small, of the upper surface, enables us to communicate, *at one instant*, the same pressure to all parts of the vessel in which the water is contained. And it will be evident, from what has already been stated, that by the skilful application of this law of hydrostatics, a vast force may be obtained, with a comparatively trifling expenditure of power. The inconvenience attending the management of a very high column of water, would of course present much difficulty in the application of this power

to machinery; and therefore, although the principle of action was known as far back as the middle of the seventeenth century, it was not considered as available for such purposes; but it has more recently been adopted by Mr. Bramah in the construction of a machine, called the *hydraulic press*, which is now used in almost every case where great pressure is required. In the hydraulic press, however, great pressure on the vertical column is substituted for the height of that column.

We have seen that in a vessel containing water, which is open at top, and the aperture of which measures an inch square, the ordinary pressure of the atmosphere would be equal to 14¾ lbs. We have also seen that if pressure or force be applied at the surface of the water, the whole mass of the liquid in the vessel will yield to the partial pressure; and being compressed into a smaller compass than it would naturally occupy, the imprisoned water, impatient of restraint, will press against the sides of the vessel with greater or less force, according to the degree of pressure exerted; and if the pressure be increased to a great amount, the water will press downwards with an equivalent force. Pressure, equal to 14¾ lbs., is usually technically termed the weight of an atmosphere; and if a pressure equal to twice that weight be applied, it is called the weight of two atmospheres; if three times, of three atmospheres; and so on. If additional pressure equal to one, two, ten, twenty, or any number of "atmospheres" be applied at the surface of the water in the vertical limb of the vessel (see diagram, p. 53), the pressure at the bottom of the vessel would be increased in proportion; and the force thus used would form a substitute for the length of the column. It is on this principle that Bramah's hydraulic press is constructed, a small forcing pump, to which any required power can be applied, being adopted as a substitute for the high column of water; and thus the effect produced, is the same as if the column of water were indefinitely long. In the practical use of this machine, a small quantity of water is driven by pressure, regulated according to the force required, into a vessel *already full*. Under such circumstances, the pressure of the

water on the sides and bottom of the vessel is enormous, and this may be increased to such an extent, that scarcely anything can resist its power; although the whole apparatus is very compact, and occupies only a small space. Thus, a man with a machine acting on this principle, and not larger than an ordinary sized tea-pot, standing before him on the table, may cut through a thick bar of iron, with as much facility as he could clip a piece of pasteboard with a pair of scissors. On a larger scale, this machine is capable of many useful applications, such as a jack for raising heavy loads, or an instrument for drawing up trees by their roots, or extracting the piles used in bridge-building. It also is very advantageously employed as a press, for compressing woollen, cotton, and other goods, into the most portable dimensions.

The tendency of all the parts of liquids to assume a level surface, renders them applicable to the formation of *levelling instruments*, or instruments for ascertaining whether any surface is level, or any line horizontal. These *instruments* are usually termed *levels*, and are of various forms; but the best and simplest instrument of the kind consists of a perfectly cylindrical and straight tube of glass, either hermetically sealed at both ends, or closed by being melted in a blow-pipe; being, however, previously filled with some liquid, so as merely to leave a small bubble of air. When the instrument is placed horizontally, the air bubble will remain stationary in the centre; but if it be not perfectly level, the bubble will rise to one or other end, according to the inclination given to the instrument. Water, spirits of wine, ether, &c., may be employed for this purpose; but the liquid best adapted for use in this instrument is oil of tartar, which is not liable to freeze, nor to be affected by changes of temperature.

The *running or spouting of water*, from the sides of vessels, arises from the hydrostatic law of lateral pressure; and, as the downward and consequent lateral pressure of the liquid, is proportional to the height of the column of water, without regard to the quantity any vessel may contain, so we shall

and that water will pour out with greater force, in regular proportion to the height of the column, without regard to the mass of water. Thus, if water issue at the rate of a gallon per minute from an orifice in a cask or cistern, situated three inches below the surface of the water, double that quantity, or two gallons, would issue in the same space of time from an orifice situated at four times that depth, or twelve inches below the surface; and three gallons would issue from an orifice situated at nine times the depth, or twenty-seven inches below the surface. The circumstance of the greater orce or rapidity with which water pours forth from an orifice at a greater depth below the surface, many of us may have an opportunity of verifying by our own observations: for, if we draw water from a cistern or water-butt, we shall perceive that when the vessel is full, the water pours forth with considerable force, whereas when the water is low in the cistern or butt, the force or rapidity with which it issues is greatly diminished, a fact which is expressed by a common, though certainly not very grammatical phrase, namely, that "it runs slow." If, however, when the cistern is half empty, we immerse in the water a bucket or other vessel, avoiding touching the sides of the cistern, but by this means causing the water to stand higher in the cistern, the height of the column, though not the mass of water, being thus augmented, the water will flow with increased rapidity in proportion to the increased elevation of the liquid in the cistern. This is, in fact, as the reader will perceive, only a repetition of the experiment before alluded to, of weighing down the scale by placing the smaller tumbler or jar, within the larger, and by this means raising the four ounces of water to the elevation at which the eight ounces had previously stood: but though only a repetition of that experiment, it is not repeated without increased interest in the present instance, on account of its here affording us ocular demonstration of the augmentation of downward pressure by increase of height in the column of water. For it will be evident, that the same principle is called into action in both cases; and in that of the

increased rapidity with which water flows from an orifice at a greater depth from the surface, we shall at once perceive that it is caused by increase of pressure. It also illustrates the hydrostatic paradox; for in this, as well as in that instance, we find that the degree of downward pressure depends on the height of a portion of the water, and not on the magnitude of the whole mass.

In ancient times, before the invention of clocks and similar time-pieces, recourse was had to various expedients for marking the lapse of time. Sun-dials could only be available during the hours of daylight, and in unclouded weather; and it therefore became an object of great importance, to introduce some other method of indicating the passage of the hours, during the darkness of night, and when the sun was obscured. One mode of effecting this desideratum, which was very generally adopted by the ancients, was the dropping of water from one vessel into an other, through an orifice of determinate magnitude; and the earliest water time-pieces, or *clepsydras*, as they are termed, probably bore much resemblance to hour-glasses, in which sand pours from one vessel into another*. The passage of time was indicated in this clepsydra, by marks corresponding either to the diminution of the water in the containing vessel, during the time of its being emptied, or the increase of the fluid in the receiving vessel, during the time of its being filled. It was soon, however, found, that the escape of the water from the containing vessel was much more rapid when it was full than when nearly empty, owing, as we shall be well aware, to the difference of pressure when the water stood at different heights in the vessel. A variation in temperature will also cause some irregularity in the action of these water-clocks, and they are likewise in some degree affected by the state of the atmosphere; but they are nevertheless susceptible of considerable accuracy,

* The era of the invention of these water-clocks is unknown; but there can be no doubt that they date their origin to a very remote period; for an instrument of this kind appears to have been in use in India about 700 years before the Christian era. These instruments are supposed to have been introduced into Egypt under the reign of the Ptolemies.

and before the introduction of clocks and watches, clepsydras formed the sole dependence of the astronomer for measuring small portions of time. These instruments, from their construction, were rather costly; and a single clepsydra appears to have been considered sufficient for each town. These "town clocks" were always attended by a slave, whose business it was to blow a horn at stated periods; and as this sound would extend to a considerable distance, notice was thus generally given of the passing hour. Nobles and persons of eminence, however, used to employ messengers to acquaint them with the time, as indicated by the clepsydra. Some of these water-clocks appear to have been more complicated in their structure; descriptions being handed down to us of clepsydras, in which the mechanical action of wheel-work was combined with the flowing of water; and which not only noted the division of the day into hours, but also the age of the moon, and the position of the sun in the ecliptic; and which, yet further, blew trumpets at stated times, projected stones, and performed various other wonderful feats. Clepsydras were introduced into Rome about two centuries before the Christian era; and Julius Cæsar, in his invasion of Britain, is said to have met with one in this island, though from whence it can have been procured is a matter of great uncertainty. The clepsydra continued to be used for many centuries; and it is related in an old chronicle, that a curious water-clock was sent by Haroon al Raschid (or Haroon the Just) to Charlemagne about the year 808, which appears to have approached in some respects to the clocks now in use. It was formed of brass, and announced the hours by means of twelve little balls of the same metal, which, at the end of each hour, produced sounds by striking against a bell. There were also figures of horsemen, which, at the same interval of time, came forth through little apertures or gates, and again retreated. In some parts of the Continent, clepsydras appear to have continued in use until comparatively modern times; but at present they are perhaps wholly superseded by pendulum clocks, and watches, which are not only far more convenient, but also infinitely more exact.

CHAPTER V.

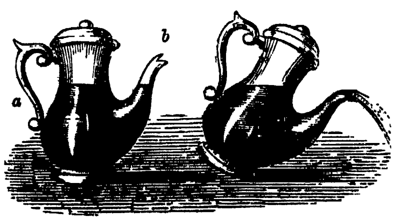
EQUILIBRIUM OF WATER, CONTINUED.

We have seen that the equilibrium of water is the great truth on which the laws of hydrostatics are based; we have further been led to observe the remarkable degree of force exercised by a column of water of considerable height, though of small dimensions, acting upon a body of water of greater surface but of small elevation, as exemplified in the hydrostatic paradox, in natural phenomena, and also in the greater or less force with which water spouts out from an orifice on the side of a vessel, according to the depth of that aperture below the surface of the water. Let us now proceed to consider the equilibrium of water as exhibited in its tendency to maintain or to assume a general level at the surface. Expansive fluids, such as air and the gases, have, as already remarked, a tendency to press equally in *all* directions: this property does not belong to liquids when unconfined; and perhaps the *equilibrium of lateral pressure*, or the equal *lateral* pressure in all directions, may be regarded as the most correct expression of the distinctive characteristic of liquids, and that in which they differ from elastic or expansive fluids.

The equal lateral pressure of water in all directions, gives rise to a vast number of interesting and important phenomena, whether we select our examples from the natural world, from the application of the principle to practical purposes, or from familiar instances of less apparent importance, but perhaps not less illustrative, because they may come under our own personal observation.

Let us commence with the most simple instance, that of a bent tube or pipe, curved in the form of the letter U. If we pour water into one limb or branch of such tube, we shall find that it will assume a level at the surface in the two branches, and that the water will stand in both at vertical heights precisely equal to each other. This circumstance, it will be evident, arises from the mobility of its parts, and its tendency to assume

and preserve a level surface; for, were it otherwise, the water would remain in the branch into which it was originally poured, or if it did ascend into the other branch, it would not present the *perfect* level which we shall perceive the liquid will invariably assume. In the example of the bent tube, both branches are of equal dimensions, and have an immediate communication with each other; but, in fact, it matters not what are the respective sizes of the two branches, nor, if the number be multiplied, nor yet, how remote they are from each other, so long as there is a free channel of communication, and a sufficient supply of water to fill all the branches. As an instance of a body, the branches of which, though freely communicating by only small orifices, have different capacities, we may take the very familiar one of a tea or coffee-pot. If we pour water into the branch having the largest capacity, or, in other terms, the body of the coffee-pot, we shall find that the liquid, instead of remaining in that branch, will simultaneously enter the lesser branch or spout, and according to the height of its level in the one, so will it be in the other; and if we continue pouring in water, until it reaches the same level as the aperture in the spout, it will rise to and appear at that point; and should this aperture be lower than the upper part of the body of the coffee-pot, the liquid would pour over until reduced to that level. If the vessel be not filled higher than to the level of *a* in the accompanying diagram, and if we desire to pour out the coffee, or what-

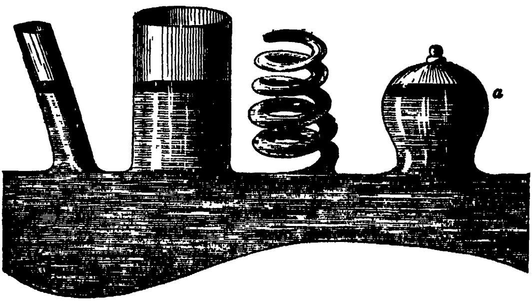


ever liquid it may contain, and accordingly incline it forwards, as in the right-hand figure, we shall perceive that, by lowering the spout, we give a different level to that portion of the branch in which this aperture is situated, in consequence of which, the

coffee,—being obedient to the fundamental law of hydrostatics, which impels all liquid bodies to assume a level at the surface, and also that of gravitation, by which all bodies fall to the earth,—complies with our wishes, and pours forth into our cups; and the facility with which the liquid will pour out of the vessel, will be much influenced by the relative elevations of the upper part of the spout *b*, with that of the tea or coffee at *a*.

Some of our readers may, perhaps, smile at our speaking of the pouring out of tea or coffee, as the result of grand natural laws; and think that the liquid "pours out," because it obeys the impulse given by ourselves: but this would be merely saying that water pours forth because it is water; whereas, we would desire to give the reason, (as far as human science can effect it,) why liquids pour forth. A solid mass, we are well aware, would not pass into the lesser branch, nor even were we to fill the larger branch with fine loose sand, would that extend itself into the spout, so as to assume a level surface in both branches: and this power of fluids, to rise in an indefinite number of branches, is, in fact, peculiar to this class of bodies, being in the most minute, as well as in the most stupendous instances, a consequence of the laws given to this peculiar kind of matter by the Creator of the universe. This is also a law of the utmost importance; for, were water otherwise constituted, the natural world could not (as far as appears to human perception) exist in its present condition. The coffee assumes a level surface in the two branches of the coffee-pot, owing to the perfect mobility of the parts of the liquid, and, had this property not been imparted to fluid bodies, we should meet with no better success in attempting to pour out the water or coffee, from the coffee-pot, than did Canute in checking the advance of the sea, when, to reprove the fulsome and absurd flattery of his courtiers, he placed himself on the borders of the great deep, and bade the waters of the ocean not approach his royal feet. The equal lateral pressure of water caused the sea on that occasion to advance to its wonted limits; and it is the same principle that causes the coffee, or any other liquid, to enter,

and rise in all the branches of any vessel or reservoir, whether natural or artificial, and whether vast or minute in its dimensions. Nor, as just stated, does it matter what may be the number of branches thus connected together, nor their various forms, whether globular, spiral, upright, or slanting, nor yet what may be the comparative depth of the several parts, so long as there is sufficient water to fill the connecting trough or basin, as at *a* in the accompanying diagram.



This law is exemplified on a large scale in the greater number of conduit-pipes in use for conveying streams from distant sources to the several parts of a city, and in some cases to the upper floors of houses or manufactories; but as the particulars relative to the conveyance of water are connected with the motion of that liquid, we shall defer the consideration of this subject until we treat of hydraulics.

Although displayed in a different manner, owing to the different circumstances attending the phenomena, it is, as we have just observed, the same hydrostatic law of equal pressure, that retains the vast mass of waters contained in the ocean, in their appointed place. "Hitherto shalt thou come, and no farther; and here shall thy proud waves be stayed," is the command which has been given to the illimitable deep by the Almighty Ruler of nature; and the command is implicitly

obeyed. But let us remember that this is not an arbitrary injunction, given to an individual subject of the vast empire of the universe, it may rather be considered as a charge reminding the waters of the sea of their subjection to the general laws which the Divine Lawgiver has instituted for all nature. The Creator has power to command every creature of his hand: but, in the ordinary course of nature, we do not find the established laws departed from for the accomplishment of any particular end; and even in cases presenting evidence of an especial Providence, God works by second causes. Divine Wisdom may decree that a district or a country should be overwhelmed by the world of waters; that another should be laid dry. The waters overpass their usual bounds, or retreat from the place they formerly occupied: but in so doing, they do not depart from their obedience to the laws of hydrostatics, and assume a higher level at that particular locality without some effective cause; they follow the hydrostatic law of yielding to partial pressure, and are either driven forward by the force or pressure of the wind, or, perhaps, are elevated by pressure from beneath, caused by the upheaving of the submarine floor, arising from the action of an earthquake. What thus at first sight appears a deviation from established laws, will, on close investigation, be found to be only a different application of these very laws, made subservient, perhaps, to some especial purpose of Divine Providence. They are "the ever-changing but unvarying responses of nature, which are prompted by the Creator Himself, and they are but the utterance of His immutability."

It is, in fact, a reliance on the constancy of the laws given to liquid bodies, that imparts a sense of security to the inhabitants on the borders of the ocean. Many human dwellings are so situated, that were the sea to advance only in a trifling degree beyond its usual limits, they would be involved in inevitable destruction. And yet, even although "the waters thereof may rage and swell," the in-dwellers rest in peace and security. They, perhaps, may not be sensible that their security arises from the fact, that water obeys the hydrostatic law of equal

pressure; but it is not the less true that this law holds in subjection the stupendous world of waters;

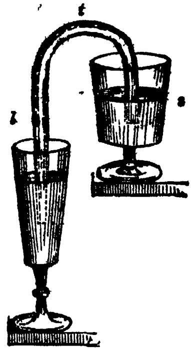
> Beautiful, sublime and glorious,
> Mild, majestic, foaming, free.

The ocean, doubtless, is subject to some fluctuations in its surface, and is frequently agitated by winds and by other causes, which occasion temporary and partial changes in its level. These perturbations, however, only proceed from the tendency of fluids to yield to the slightest partial pressure; and, in the case of the ocean, this pressure may arise from solid rocks which obstruct the free passage of its waters, from winds of greater or less force, or from the atmosphere itself. The latter, as we have already seen, exerts a continual average pressure on all parts of the earth at the sea-level,—and consequently on the ocean itself,—equivalent to 14½ pounds for every inch square: and since the atmosphere is subject to variations in its density, some of the fluctuations occurring at the surface of the ocean, may, perhaps, originate in atmospheric changes.

In the phenomena of waves, we meet with an exemplification of two of the leading principles of hydrostatics:—the yielding of fluids to the slightest partial pressure, and the equilibrium of fluids. Every passing breeze that agitates the mass of waters illustrates the former; and were it not for the counteracting forces opposed by the latter, the water would be driven onwards in one direction by the pressure of the winds, and form currents, instead of waves.

The action of the well-known instrument called the *siphon*, or *syphon*, also depends on hydrostatic equilibrium. A siphon consists simply of a bent tube, as represented in the accompanying diagram, having one end longer than the other. To use the siphon, the tube is, in the first place, filled with water or whatever liquid we may wish to draw off from the upper vessel; and the open end of the longer branch *l* being stopped by the finger or by a cock, the water will not flow from the other extremity, owing to the pressure

of the atmosphere from beneath*, and we are, therefore, able to turn it in the reversed position as shown in the diagram, without spilling a drop of water. The shorter end *s*, is thus immersed in the liquid to be drawn off, and the finger being removed from the orifice at *l*, this will immediately begin to flow out from thence, and continue flowing until the liquid is drawn off to the depth of the orifice at the end of the shorter branch *s*. It might, at first sight, appear that, instead of depending on hydrostatic equilibrium, the action of the siphon formed an exception to that general rule; for it will be evident, that at the top of the siphon *t*, the water rises above the surface-level of the water in the upper vessel, and, therefore, its equilibrium *seems* to be destroyed. The explanation of this apparent anomaly is, however, very simple, and, at the same time, highly illustrative of the effect produced by the pressure of the atmosphere. The fact is, that when we fill the tube with water, the air is wholly excluded, and, therefore, there is no atmospheric pressure at *t*; but the ordinary atmospheric pressure of about 14¼ pounds for every inch square presses on the water in the upper vessel: and so long as the height of the column of water in the branch extending from *s* to *t* is not so great as to counterbalance, by its weight or pressure, that of the atmosphere, that is, about 33 feet, the atmospheric pressure on the water in the upper vessel or tumbler, will force the water up into the tube; whilst, by its natural gravity, it will flow down the longer branch, and issue forth in a continued and regular stream, until the whole of the water is drawn off, to whatever depth the end of the shorter branch may be immersed. It is absolutely necessary to have the branch from which the water is designed to issue, longer than



* Expansive fluids, such as atmospheric air, we may remember, press equally in *all* directions.

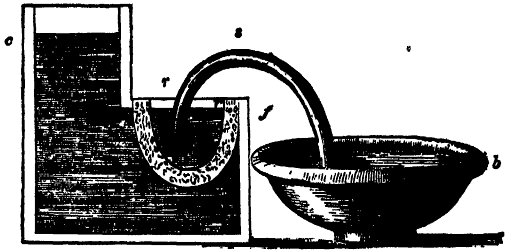
that immersed in the water to be drawn off; for if they were of precisely similar lengths, the atmospheric pressure from beneath, acting upon the orifice of the former tube, would be equivalent to the atmospheric pressure on the water in the tumbler, and would exactly counterbalance it. In such a case, therefore, instead of the water pouring forth from that orifice, the no less striking phenomenon would be presented of the water remaining stationary in the tube, instead of flowing out from thence. The whole affords a singularly clear and striking example of the equal pressure of *fluids* in *all* directions; and also of the downward pressure of water according to the length of its column: for, precisely in proportion to the length of the external, or longer branch, will be the impetus with which the water will issue.

From the above description, it will be evident, that, although the siphon does raise water above its level, this is only effected by the removal of the pressure which otherwise would maintain it at its level; and that, therefore, it forms no exception to the laws of hydrostatic equilibrium.

The siphon is very useful for drawing off wine or any liquid, if it be required to remove the upper part without disturbing the lower. It is also generally used for drawing off water from filtering-machines, in which the water is filtered by percolating upwards through the stone, instead of in a downward direction. A filtering-machine of this kind forms so clear and striking an illustration of the tendency of water to find its own level, that some description of the whole apparatus may not be without its utility.

In the accompanying diagram, *c* is a cistern, filled, as we may suppose, with water from the river Thames, which requires to be filtered ere it be fit for use: *f* is the porous filtering stone, through which the water is to pass *upwards*, into the receiver *r*; *b* is a reservoir or basin into which the purified water is to be conveyed, and *s* is the siphon through which it is to pass from the one vessel to the other. The water in the cistern being confined in all directions by the sides of the latter, and being pressed from above by the weight of the atmosphere,

forces its way, in the act of finding its level, upwards, through the porous stone into the receiver *r;* and from thence it is removed, by means of the siphon, into the reservoir or basin,



from whence it may be conveniently drawn for use. And, so long as the water in the supplying cistern is of sufficiently high level, so long will the water continue to force its way through the porous stone into the reservoir. Filtering-machines of this kind, possess considerable advantages over those which are constructed on the principle of the downward filtering of the water; for the latter are liable to become speedily choked up by the deposits from the water, which necessarily all settle on the upper surface of the filtering-stone itself; whereas, in the filtering-machine above-described, the greater portion of sedimentary matter is deposited at the bottom of the cistern, and it is only the minute particles which are held suspended in the water, that are arrested by the filtering-stone.

CHAPTER VI.

NATURAL DESCENT, OR FLOWING OF WATER; IN STREAMS; AQUEDUCTS; AND PIPES.

THAT branch of hydrology which is distinguished by the term *hydraulics* will form our next subject of consideration.

The object of hydraulics is to investigate the means by which the motion of water is produced, the laws by which it is

regulated, and the force which water in motion exerts against itself, or against other bodies. It accordingly treats of the motion of water, whether flowing in pipes, canals, or rivers, whether oscillating in waves, or whether opposing a resistance to the progress of solid bodies. It will be evident that this branch of our subject must therefore comprise much that is of extreme practical utility: we may also add, that it includes much that is highly interesting, especially to those who delight to trace the causes of phenomena of daily occurrence, whether presented in the natural world, or in the application of the motion of fluids to mechanical and other uses for the benefit of man.

The subject may be divided into three heads: first, the effects which take place in the *natural* flowing of water through the various ducts or channels along which it is conveyed; secondly, the artificial means of producing motion in water by mechanical forces; thirdly, the power or force which may be derived from water in motion, whether that motion be produced naturally or artificially.

The *natural flowing of water*, and of all other liquids, arises, as we have seen, from the law of gravitation, common to all matter, combined with the hydrostatic law of equal lateral pressure in all directions. The law of gravitation causes the water to descend to the lowest possible level, or in other terms, causes it to make the nearest possible approach to the earth's centre; and this, whether the descent be perpendicular, or nearly so, as in a cascade, or whether it consist only of an inclined plane of comparatively small slope, as in the bed of a river. The hydrostatic law of equal lateral pressure causes the stream of water, when once it escapes from its confinement, to flow onwards and spread itself on all sides, where not obstructed by any impediment; filling up all the inequalities of the bed over which it passes, and forming a level, though inclined surface; thus proceeding on its course until it unites its waters with those of some other stream, of a lake, or of the mighty ocean itself; unless indeed it may be absorbed in the sand, like many of the rivers of Australia, or, in its attempt to

reach the centre of gravitation it may precipitate itself into chasms, like the river Drôme, in Normandy, which, to use the local phrase, is "drunk up" by some gulfs or chasms, which are situated in the midst of an extensive meadow, and the largest of which is about thirty or forty feet in diameter.

The rapidity with which a stream flows depends partly on the slope or inclination of its bed, partly on the direction of its course, whether that be straight or winding, and partly on the volume or mass of waters: and, accordingly, as these conditions vary, so will the velocity of a stream of water vary, whether in a river, or in an artificial duct or channel of any kind Thus, in mountainous districts, rivers usually flow with considerable rapidity, frequently forming at first impetuous torrents, wholly unfit for navigation; but when they enter more flat districts their character is changed, and they proceed across the level plain with a calm and majestic demeanour. When a river is very winding in its course, a great decrease in its rapidity will ensue; for the numerous turns the river takes reduce the amount of the declivity of its bed, and at every bend of the stream, the banks will present some obstacle to the free flowing of the water. Such irregularities in the beds of rivers frequently produce eddies, and every eddy destroys part of the moving force of a stream of water. According to Major Rennell, the windings of the River Ganges, in a course of eighty miles, are so numerous, that they reduce the declivity of the bed to four inches per mile, the medium rate of motion in the stream not exceeding three miles per hour, the river at the time having a depth of about thirty feet. The same river, when full, affords an example of the increased velocity with which a stream flows when its mass of water is greater; for at that period, the volume of water in its channel being increased to about three times its previous quantity, the motion of the river is accelerated to five miles per hour.

The flowing of water down any descent is familiar to all, but this, as well as other phenomena of nature, may pass continually before our eyes without our considering that it is the consequence of one of the fundamental laws of nature; and

Where threatening ploughs have tried in vain
To till the sandy soil;

and also that, in too moist districts, the superabundant waters may be carried off by drainage; and thus, besides numberless other advantages, extensive tracts of country may be recovered, and rendered available for cultivation, and for the abode of man.

In ancient times, water conduits appear to have been constructed solely with reference to the *descent* of water, and without regard to the important principle of its finding its level. These works were therefore conducted at a very great expense, for, if a solid rock lay in the direction in which the water was to be conveyed, it must either be penetrated, and an inclined tunnel carried through the mass, or perhaps a very circuitous route be adopted; and if plains or valleys were to be crossed, raised aqueducts must be erected for the purpose of carrying the water from one elevation to another. Some of the ancient works of this description are very splendid, and remain to this day as memorials of the greatness of their constructors. The artificial water-courses of the Greeks appear generally to have consisted of excavations, and the introduction of aqueducts raised on arches is considered as due to the Romans. As an instance of the former, we may mention some remains described by Colonel Chesney at Seleucia Pieræa*, in the Bay of Antioch. These remains present a series of extensive excavations, cut through the solid rock, partly consisting of regular tunnels, executed with great skill, and partly of a deep hollow channel of considerable width, but varying in

* This city was built by Seleucus Nicator, to celebrate his victory over Antigonus, B.C. 301; "but," observes Colonel Chesney, "it has a much deeper interest to the Christian, from being the spot where Paul and Barnabas embarked for Cyprus."

The water conduits of the Romans were constructed on a singularly magnificent scale. Their aqueducts consisted of a series of piers, connected by semi-circular arches, so as to form one continuous line, on the summit of which the conduit or channel for the water was placed, attention being paid to the necessary inclination for the fall of the water. The conduit had a paved or tiled floor, and walls of solid brick or masonry, covered either with a transverse arch, or by a simple flat coping-stone. The situation of the city of Rome, in the midst of a flat marshy plain, and the consequent deficiency of supplies of good water, adequate to the demands of a vast and populous city, probably directed the attention of the Romans to this subject, and thus led to the introduction of these raised aqueducts, by which means abundant supplies of pure water might be conveyed from distant sources, across the Campagna to the very heart of the city.

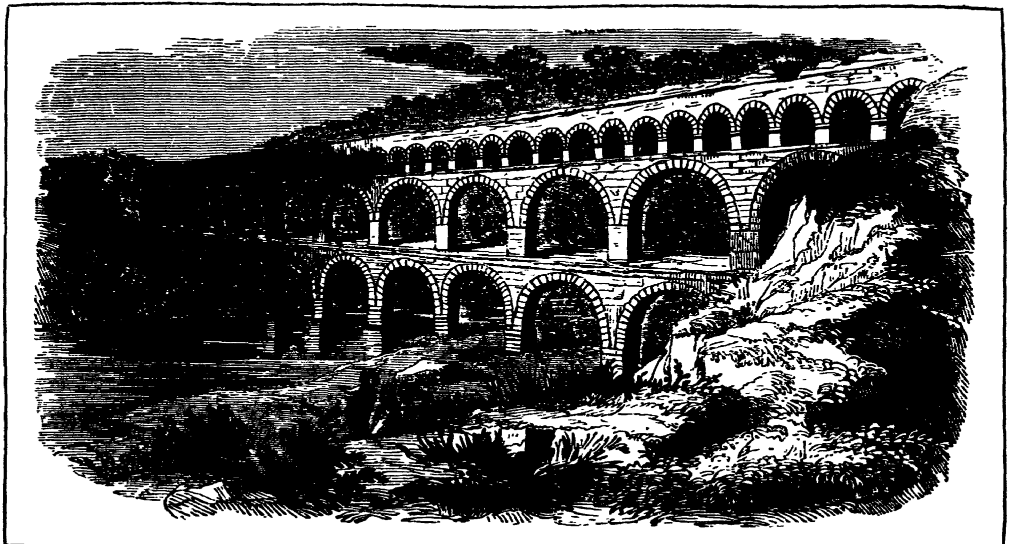
The extent and importance of the Roman works of this description will in some measure be apparent, when we consider that Rome was furnished with water from sources varying in distances from thirty to sixty miles, and that at one period of its history, no less than twenty aqueducts brought as many streams of water across the Campagna,—

> From yon blue hills,
> Dim in the clouds, the radiant aqueducts
> Turn their innumerable arches o'er
> The spacious desert, brightening in the sun;
> Proud and more proud in their august approach.

The remains of these simple though splendid works, which still radiate in almost every direction from the city, may be ranked among the most interesting as well as most beautiful of the existing ruins of imperial Rome. Among the more remarkable of these structures, was the aqueduct of Quintus Martius. This commenced at a distance of thirty-three miles from Rome, but took a circuitous route, by which the length

of its course was much increased; and, for the distance of thirty-eight miles, it was carried along a series of arches, at the elevation of about seventy feet. It consisted of three distinct channels placed one above another, and which conveyed water from as many different sources. Another remarkable aqueduct was that called the Aqua Claudia, which was begun by the Emperor Claudius and finished by Nero. This aqueduct conveyed the water from the distance of thirty-eight miles, and in part of its course passed through high ground, in which extensive excavations were accordingly required, and it thus formed a subterranean stream thirty miles in length, whilst in the remainder of its course it was supported on arcades. Such was the solidity of this magnificent structure, that it continues to the present day to supply the modern city with water. Another celebrated aqueduct was that which brought the waters of the river Anio to Rome, from the distance of sixty-three miles, and of which above six miles consisted of one continued series of arches, many of them upwards of one hundred feet in height. When all the aqueducts of Rome were in action, the supply of water furnished to the city by this means must have been enormous, and is supposed not to have fallen far short of fifty million cubic feet of water daily. Modern Rome is abundantly supplied with water by three of the ancient aqueducts; which, however, have undergone repairs and restorations in recent times.

Remains of Roman aqueducts, of at least equal splendour, also occur in various other parts of Europe to which the Roman dominion extended. Among these the most celebrated are the Pont du Gard, near Nîmes, in the Department du Gard in the South of France; the aqueduct over the Moselle, near Metz; and the aqueduct of Segovia, in Old Castile. The Pont du Gard (of which a representation is here given,) was designed to convey the waters of the fountain of Aure to the town of Nîmes, the ancient Nemausus. This aqueduct crosses the valley and the stream of the river Gardon, uniting two steep hills by which the valley is bounded at this place. It consists of two tiers of large arches, the lower



Pont du Gard.

of which are eighty feet in span, and a third tier of small arches, which supports the trunk of the aqueduct. The channel for the water is above four feet wide and five deep, and is lined with cement three inches thick, and covered with a thin coating of red clay. The whole work, with the exception of the above-mentioned channel for the water, is built without mortar or any other cement; and its elevation above the bed of the river Gardon is not less than a hundred and fifty feet. The river does not, in summer, occupy more than one of the arches of the lower tier; but during the winter floods, its stream is swollen so as to occupy the whole. The extremities of this fine structure are in a dilapidated condition, but the remainder is in a very good state of preservation. The aqueduct near Metz (the ancient Divodurum) extended across the Moselle, a river of considerable width at this place, and was designed to convey the purer waters of the little river Gorse, from the distance of eight miles into that city. The water was collected in a reservoir, from whence it was conducted for a considerable length by subterranean channels, which were formed of hewn stone, and of such magnitude, that a man might walk in them upright. The arches on which the aqueduct was raised, appear to have been fifty in number, and fifty feet in height at the loftiest part. Some of the arches which stood in the river, have been swept away by the masses of ice borne down the stream, but those on the banks still remain in a good state of preeervation. The aqueduct of Segovia, which was executed in the time of the emperor Trajan, is in a more perfect state of preservation than that of Metz; and like the Pont du Gard, it is formed of huge stones united without cement. This aqueduct consisted of two rows of arches, the one above the other, the whole height of the edifice being about one hundred feet, and passing at a higher level than the greater part of the houses in the city. About a hundred and fifty of its arches yet remain.

In more modern times, aqueducts have been constructed in various countries. Some of these water conduits, like those of the Greeks, consist of excavations or channels cut of the

solid rock; such is the aqueduct recently discovered at the once celebrated town of Aden, on the coast of Arabia. This aqueduct extends upwards of eight miles into the interior, and is built of red brick and stone, being about four feet six inches in width, whilst the inclosed water-course measures nineteen inches by sixteen. There are no remains of arches, and the general appearance is that of a mound about five feet high, and bricked over*. It is supposed to have been the work of Suleiman the Magnificent, who flourished in the beginning of the sixteenth century. The once flourishing Aden is now, however, a heap of ruins; the aqueduct no longer conveys wholesome water to the spot, and the brackish and almost undrinkable water at present met with in Aden, forcibly indicates the vast importance of this mode of supplying the city with that liquid from a more remote source: and probably good water may have been thus brought to Aden from the neighbouring valleys, some of the springs in those localities being remarkable for their purity and excellence.

One of the most remarkable aqueducts constructed on arches in modern times, was commenced by Louis XIV., in 1684, for the purpose of conveying the waters of the river Eure to Versailles. It extends about 4400 feet in length, and is upwards of 200 feet in height. It contains 242 arcades, each divided into three rows, forming altogether 726 arches of fifty feet span.

There are, however, serious inconveniences attending this kind of conduit; for, if the spring from which the supplies are to be derived, be situated at a great distance, the work can only be effected at an enormous expense. If again, the source should be situated at a considerable elevation, and in the near vicinity of the city, the inclination or slope would be such as to cause the waters to flow with so great a degree of velocity, that it would endanger the safety of the whole fabric; for, on any slight increase in the volume of water, the pressure would be so great, that the covering arch, or stone coping of the

* Until very recently, this aqueduct was regarded as the remains of a Roman road.

channel, would be blown up, or burst; and serious inundations would occur in the country across which the aqueduct was carried. To remedy, or rather to avoid this evil, and to reduce the flow of the water to a proper velocity, the stream, under such circumstances, must be carried in a circuitous direction, so as to expend, in a greater length, the excess of elevation of the source from whence the water is derived.

Modern science has, however, put a stop to the construction of these magnificent but expensive fabrics, which are now almost wholly superseded by the introduction of the less picturesque, but far more generally available conduits—cast-iron pipes. But it is in fact the knowledge and application of the hydrostatic law of the equilibrium of water, that have given the death-blow to these erections, and led to the very general and continually increasing introduction not only of pipes to convey water on hydraulic principles from distant sources, but also of artesian wells in many districts where until this principle was brought into practice, no pure water could be obtained.

When in an open channel, water will, as we have seen, descend by its gravity to the lowest possible level it can reach. If, however, we wish to take advantage of its tendency to preserve a level surface, we must not allow it its full liberty, but confine it in pipes or other ducts; and in this case we shall find that it will re-ascend to very nearly the same level, as that from which it originally started; on the same principle that water will extend into all the different branches of a vessel as shown in the diagram, page 64; the difference in its attaining precisely the same level, being accounted for by the peculiar conditions in which it is placed. Upon this principle, therefore, water, if confined in pipes, may be conveyed from an elevated source, caused to descend into a valley, after traversing which it may ascend a second elevation, without the aid of mechanical power, or any artificial means, and solely by its natural tendency to assume a level surface. This is realized on a large scale in the *soutérazis* of the Turks. "The term *soutérazi* signifies equilibrium of water, and is justly applied," observes M. Arago, "by the Turks, to the conduit pipes which

they substitute for the ancient more splendid aqueducts. These *souterazis* consist of pipes or channels, formed either of stone, of brick, or of metal, which are laid down so as to follow the undulations of the ground, across which the water-course is to be carried. They are sometimes carried for several miles, sloping down the declivity of one hill, in which the source is situated, extending across a plain, or valley, and there following all the undulations of the surface; then, perhaps, crossing the summit of a second hill, traversing a second valley, and finally ascending a third eminence, and there discharging the required supply of water, at an elevation little inferior to that of the source on the first hill. The whole being effected, as will be evident, solely by the natural lateral pressure of the water, and its tendency to find its level."

In our own country we have no specimen of a regular aqueduct, in the proper acceptation of the term; and in ancient times the citizens of London appear to have contented themselves with the supplies obtained from the Thames and from various other streams of smaller size, such as the Fleet and its tributaries, which flowed into the Thames, at no great distance from the present Blackfriars Bridge, but the very existence of which is now scarcely known, though the locality is still indicated by the street which bears the name of that ancient streamlet. Holbourne was undoubtedly the name of another rivulet, and the so-called Holborn-bridge, may be considered as marking the spot where in olden times a bridge extended across this small tributary of the Thames. Water-carriers were employed, who brought this necessary of life from these various sources, probably, however, not always of the purest kind. Some supply was doubtless also obtained from wells and fountains; but in those days, the construction of these works was too expensive for them to be by any means general, and they were principally confined to the gardens of the religious houses, and a few public localities. As the city increased in size, and its streets extended to a distance from the river, the mode of obtaining supplies of water by means of water-carriers, became inadequate to the wants of the inhabitants, and was also attended with great inconvenience. By

degrees, the small tributaries to the Thames, probably at no period of much importance, lost their character of streams, and passing as they did through a thickly inhabited city, became converted into unseemly ditches, the water of which was wholly unfit for use. In order, therefore, to obtain supplies of purer water, modes were devised of furnishing the city with that all-important article from more distant sources, and conduits were accordingly erected. The first of these conduits appears to have been introduced during the reign of Henry the Third, in the year 1236, at which period water was brought into the metropolis from the village of Tyburn, the site of the present Connaught Place. To accomplish this object, nine wells * were sunk at the latter place, and the water was conveyed from thence into the city by means of leaden pipes; and, owing to the elevation of the village of Tyburn above the city, the declivity was sufficient to admit of its passing from the one locality to the other, by the natural flow of the water. This attempt was soon followed by others, and water was brought in a similar manner from Islington, Hackney, Hoxton, and other places. Towards the end of the sixteenth century, water was also raised from the Thames by means of machinery, and yet, notwithstanding all these modes of obtaining water, a scarcity of water was still experienced in the continually increasing city. It was not, however, until the year 1613, that any really important water-course was formed; at that period—

> * * * From Chadwell's spring
> To London's plains, the Cambrian artist brought
> An ample aqueduct†.

This aqueduct, known as the New River, derives its principal supplies of water from a copious spring at the village of Chadwell, which is situated between Hertford and Ware, and from the Amwell, a small stream, a tributary of the River Lea, the source of which is also near the former. These united waters

* These wells were still retained by the city of London until the beginning of the last century.

† Sir Hugh Middleton, who accomplished this grand undertaking, was a native of Wales.

are conducted by an artificial channel, in some parts raised by dykes and embankments very considerably above the level of the country it traverses, and in others passing through excavations below the surface of the ground. This channel, which is nearly forty miles in length, terminates in four reservoirs, situated at Clerkenwell, and known by the name of the New River Head. From this point there is sufficient fall, for the lower parts of the city to be supplied by the natural descent of the water, and thither it is accordingly conveyed in pipes. To accomplish supplying the more elevated parts of the city, and also the raising of the water to the upper floors of houses, a powerful steam-engine is employed to force the water upwards into more elevated reservoirs, which from their greater height, and the tendency water has to find its level, admit of the ascent of the liquid to proportionate elevations. By this means a very considerable part of the city of London is supplied with good water from a distance of nearly forty miles, and this, chiefly by the water's natural gravitation, and with very little expense, besides the construction of the channels and conduits through which it is conveyed. The quantity of water daily supplied to the metropolis from this source is very great, being about two million cubic feet, or more than thirteen million gallons of water.

The total quantity of water required for the daily supply of all the inhabitants of this vast city, and for the use of the various manufactories, including a certain portion which always runs to waste, however, greatly exceeds that quantity, being considered not to be less than thirty million gallons. The New River, therefore, is not by any means adequate to the demand, and the remainder is derived from the River Thames; a large portion of the latter being delivered at very considerable elevations above the level of the river, by means of steam-engines. The above-mentioned quantity of water appears enormous, and there can be no doubt that the numerous inhabitants of London could exist with a far smaller supply; this abundance is, however, highly advantageous, and very conducive to the general health of the metropolis; for, owing

to the large portion of water continually suffered to run to waste, the cleansing of drains and sewers is effectually accomplished; and the importance of ensuring large supplies of water in case of fire, is too obvious to be dwelt upon.

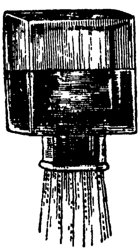
The arrangement and construction of pipes, and other ducts, for the conveyance of water, is an object of considerable importance. It is requisite that they should possess a sufficient degree of inclination for the water to flow freely; but at the same time care must be taken not to impart to them an excess of inclination, because, in the latter case, the water would flow with too great velocity. The linear disposition of pipes forms another important consideration in the artificial conveyance of water. It will be obvious, that water and other liquids will flow more freely through a pipe carried in a straight line, than through one having numerous curvatures; for every turn or bend in a water-pipe causes some obstruction to the progress of the fluid. In very many cases, however, such bends are unavoidable; and all that can be done is to attend to the construction of the pipes, so that they shall offer the least possible resistance. And since it appears that the more acute the angle, the greater will be the obstacle to the free flowing of water, it will necessarily follow that a large sweep or curve is the best form that can be adopted, where such a bend is required.

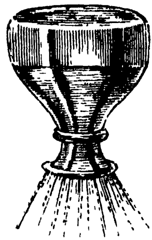
Another impediment to the free flowing of water is the *friction* it encounters from the channel or pipe along which it passes. For, though the obstruction which water encounters from rubbing against the sides or beds of channels, does not at all approach in force to that encountered by solids, it is of sufficient amount, to render it an object of importance in allowing for the velocity of the discharge of water, through pipes of any great length. This can only be obviated, by making pipes of larger dimensions than would otherwise be required; for, since the friction, and consequent resistance, only takes place at the sides of the pipe, and not in the centre, the water which is in contact with the sides, moves less rapidly than that in the centre. If, therefore, we wish water to flow through a pipe,

at the rate of fourteen inches per second, and give it a corresponding inclination, we must also take care that the pipe be of sufficient bore, to admit the required supply of water to pass through the centre, and not wholly to fill the pipe. The river Neva, when covered with its annual coating of ice, resembles a vast pipe, through which the water flows; and the experiments of M. Raucourt have shown, that it is subject to the same laws as those displayed by water passing through pipes. The river, in the locality where the experiments were made, is 900 feet in width, and the greatest depth is 63 feet. In this mighty pipe it was found that the *maximum*, or greatest velocity of the water, which was two feet seven inches per second, occurred in the centre of the stream, and midway between the top and bottom. Near the top, the retardation caused by the friction against the ice, reduced the velocity to one foot eleven inches per second, whilst near the bottom it did not exceed one foot eight inches per second.

In short pipes, or channels of any kind, the friction against the sides causes the water to flow with an unequal motion in the different parts of the pipe; but when it flows through pipes or canals of sufficient length, the resistance is counterbalanced by the force of gravity, and uniformity in the motion of the stream is thus produced.

Besides attending to the construction of pipes, we must, if we wish for a rapid discharge of water, attend also to the form of the orifice through which it issues. Now, if we were desirous of emptying the water with the greatest possible rapidity, from a vessel or reservoir, we should find that the volume or quantity of water, flowing from a round hole at the bottom, would not be so great, as that discharged through a short pipe affixed to, and projecting from, the cistern, as represented in the accompanying diagram. But, if we would effect the most rapid possible exit of the water from the vessel or reservoir, we shall accomplish this by terminating





the short pipe, in a curve similar to that figured in the annexed diagram. If, however, in either of the latter cases, the pipe, instead of only projecting externally from the vessel, were to be extended within it, no such effect would be produced; but on the contrary, the increased velocity gained by the addition of the pipe would be more than counterbalanced by the opposing currents of water, which would strike the bottom of the vessel, on either side of the portion of the pipe extending within it. For the rapid discharge of any liquid from an orifice of similar dimensions, it would thus appear, that there is no form superior to that of a common water caraff, or wine-decanter.

CHAPTER VII.

PHENOMENA OF SPRINGS; AND OF ARTESIAN FOUNTAINS.

The same forces—the natural gravitation of water, and its equality of pressure—which, as we have seen, cause the water to pass by means of pipes, often of considerable length, from elevated reservoirs to the upper floors of houses, first descending and then re-ascending, and which are also exhibited in the *soutérazis* of the Turks, give rise to artificial *jets d'eau*, as likewise to natural springs and fountains. The *soutérazis* before described, may assist us in illustrating the phenomenon of artificial *jets d'eau*. Let a pipe be arranged in the same manner as is practised in those Turkish water-conduits; that is, descending from a hill, and extending across a valley or plain. But, instead of ascending a second hill, let the pipe terminate abruptly in the middle of the valley. Let an orifice be then made in the *upper surface* of the pipe, and we shall find, that the water will spring up out of it in a vertical direction, the height of the jet or fountain being in proportion to

that of the sheet or reservoir of water, from whence it is supplied. The external jet or play, of the water, would therefore be highest in the lowest part of the valley, owing to the greater comparative elevation of the reservoir above that spot; and if we were desirous of obtaining a jet of water of equal height half way down the hill, we must raise our reservoir to a corresponding elevation above the latter locality. Such, in fact, is the mode of operation of all fountains of water, whether natural, or of artificial construction.

Turning to the natural world, we find vast reservoirs existing in the interior of the earth, an abundant supply being thus provided for the benefit of the creatures of God's hand, though, perhaps, of more especial utility to man. If, however, these reservoirs of water perpetually maintained their position in the interior of the earth, and were never to emerge to the light of day, their utility would not be so apparent. Such, however, is not the case. Some of these reservoirs, it is true, may remain undisturbed until the ingenuity of man may devise modes of arriving at these hidden treasures; but so soon as they can obtain an outlet, they are ready to obey the laws of nature, and rise to the surface, or within a short distance of it, according to the elevation of the sheet of water by which they are fed; or, in other terms, according to the height of the column of water which presses upon them.

But the question may, perhaps, arise, How are these subterranean sheets of water formed, and what reason is there to conclude that such pressure is exerted? To this inquiry an answer is afforded by the researches of the geologist. It appears that the earth's crust is, in most parts, composed of numerous alternating strata, some of which, such as sand, or gravel, are *permeable*, that is, are porous, and, consequently, freely admit the passage of water through their substance; whilst others, such as granite, clay, &c., are *impermeable*, or will not allow of its passage. If, therefore, rain fall on a bed of gravel or sand, resting on a substratum of clay, the rain will sink through the interstices of the former, until it reaches the clay, which will arrest its further progress, and form the

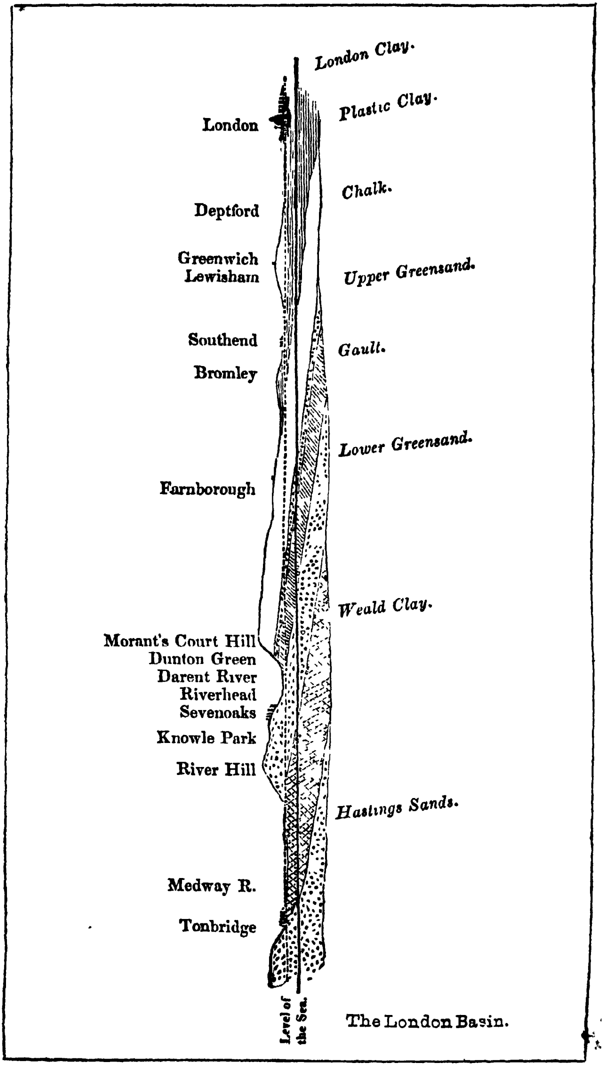
bottom of this natural reservoir. Under such circumstances, all the interstices of the lower part of the porous bed would be charged with a subterranean sheet of water. If the strata were arranged in a strictly horizontal position, the water would fill this bed, and might extend for a vast distance, whilst we should have no means of obtaining access to it on hydrostatic principles, and it would maintain its position in the interior of the earth, perhaps flowing onwards in a slow subterranean stream, until it arrived at some natural cliff which afforded it an outlet, when, from its natural gravity, it would gush forth. An instance of such a spring is mentioned by Captain Fitzroy, as occurring on the banks of the Rio Negro, in Patagonia. The banks of this river rise in that locality like a perpendicular cliff, 100 feet in height, of which the lower portion, to the height of about 60 feet, consists of a bed of clay, whilst the upper portion consists of a bed of sand and gravel. At the point of junction, that is, at the upper surface of the clay, and the lower region of the gravel, a copious spring gushes out from the cliff, forming a natural jet d'eau, pouring forth with considerable impetus into the river, though varying, of course, according to the depth of the supply of water in the subterranean sheet.

If, however, such a subterranean sheet of water, instead of arriving at a cliff, open to a river, or to the ocean, were to arrive at, or terminate in a mass of impervious rock, such as granite or clay, the water would be prevented from extending further; so that, if quite horizontal, and having no free outlet, it would, instead of gushing forth as a spring, accumulate and become stagnant, forming a marsh or swamp, or, perhaps, an almost inaccessible subterranean sheet of water. But although occasional instances may occur of flat horizontally disposed strata, this is by no means the most general arrangement of the beds on the earth's surface; for, in this case, we must suppose the permeable bed to be uppermost, because otherwise no rain-water would ever enter into the interior of the earth, but would sweep over the surface in torrents, not unfrequently perhaps destroying whatever might lie in their course, and thus proving injurious, instead of beneficial to the face of nature. In the greater

number of instances, however, we find, that though the strata sometimes maintain a horizontal direction, for a considerable extent of country, in other parts they are considerably inclined, or even placed perpendicularly to the horizon, presenting the appearance of having been rent and thrown out of their natural position by the action of a powerful force from beneath; and by such means immense basin-shaped valleys have been formed, the consequence of which is, that the edges of the strata are often exposed, in the flanks or rim of the basin, to the action of the atmosphere. The London Basin, or the valley in which the city of London stands, will form a good illustration of this arrangement of the strata.

It will be sufficient for our purpose if we take one side of the basin, which will enable us to give it on a larger scale.

In the vicinity of the metropolis, the London clay, it will be observed, fills up the hollow or depression, forming the upper stratum or bed. This being impervious to water, the consequence is, that a large portion of the atmospheric water which falls on this surface, instead of sinking to any depth, drains off to the most depressed portion of the stratum of the London clay, which, in fact, forms the bed of the river Thames, lending its aid in increasing the magnitude of the river. The stratum immediately below the London clay, it will be seen, bears the name of Plastic Clay: this formation is not, however, wholly impermeable, but contains, in some parts, beds of coarse gravel and sand, alternating with the clay, and forming subterranean reservoirs of water. The plastic clay extends as far as Farnborough, and the substratum immediately below the latter, consists of a bed of chalk, which, it will be seen, passes under the city of London, beneath the beds of London clay and plastic clay, but which rises to the surface, and constitutes the high ground in the neighbourhood of Morant's Court Hill. This mass of chalk, which is no less than 700 feet in thickness, is permeable to water, as is also the subjacent Upper Greensand, (called likewise ironstone and firestone). These strata, however, rest upon a stratum of gault or blue clay, which is retentive, or impermeable to water, and, consequently, arrests its


London Clay.
Plastic Clay.
Chalk.
Upper Greensand.
Gault.
Lower Greensand.
Weald Clay.
Hastings Sands.
London
Deptford
Greenwich
Lewisham
Southend
Bromley
Farnborough
Morant's Court Hill
Dunton Green
Darent River
Riverhead
Sevenoaks
Knowle Park
River Hill
Medway R.
Tonbridge
Level of the Sea.
The London Basin.

progress, and admits of an accumulation of water in the whole area between the London or the plastic clay, and the blue clay. And since a large portion of the chalk *crops out*, or comes to the surface, between Farnborough and Dunton Green, as well as in all the other localities which form the chalk-margin of this large basin, an opportunity is thus afforded for the entrance of snow and rain-water through this permeable stratum. And further, owing to the sloping form of the basin, the liquid will naturally descend to the lowest point, that on which the city is situated; forming in that locality, a vast reservoir, which, being protected from evaporation by the covering of clay, suffers no diminution of quantity by natural means. It will be seen, that beyond the region of gault, or blue clay, another stratum succeeds called the Lower Greensand: this is again permeable; but is succeeded by that called the Weald Clay, which is impermeable. These strata also take the same direction, apparently forming portions of the great basin; and we may, therefore, conclude that beneath the gault, a second subterranean reservoir of water may exist, fed by the supplies received from the atmosphere at River Hill, Knowle Park, Sevenoaks, and the adjacent country, in the same manner that the chalk reservoir receives its supplies from the high ground at Morant's Court Hill, &c.

These vast reservoirs accumulated beneath the city of London and its vicinity, would, however, be of little avail to its inhabitants, were it not for the hydrostatic principle of equal pressure; for the London clay is in many parts of great thickness, and if it were requisite to sink wells and to draw up water from the depth of 300 feet or more, the labour would render the task a very unprofitable undertaking. But, owing to the equal pressure of water, and its natural tendency to find its level, if we penetrate through the bed of clay, so as to enter the chalk reservoir, the water, on meeting with an outlet, is found to rise up, exactly in proportion to the elevation and consequent pressure of the water contained in the chalk stratum; so that, if the water were on a level with the dotted line, we should find that it would rise to the surface at Deptford,

Lewisham, and Southend; but would not rise to the surface at Bromley. And if the surface of the ground in any part of the basin should be lower than the dotted line, then, not only would it, in finding its level, merely reach the surface, but would naturally rise higher, thus causing a perpetual jet or fountain of water. Such is the principle on which *Artesian fountains, or wells*, are constructed; these being in fact, nothing more than vertical perforations of small diameter, made through the upper strata of the earth, and carried on, until a subterranean sheet of water is met with, which will give rise to perpetually flowing fountains. It frequently happens, that after passing through hundreds of feet of retentive soils, a water-bearing stratum is at length pierced, and the fluid then immediately ascends to the surface, and flows over. The first rush of the water up the tube is often very violent, and the water for a time is thrown up to a considerable height, playing like a fountain; but, ere long, it ceases to rise with similar force, and continues to flow more tranquilly. This violent spouting of the water on its first finding an outlet, is considered to be owing to the disengagement of air and carbonic acid gas, both of these having been observed to bubble up with the water. To prevent the sides of the bore from falling in, and also to avoid the spreading of the ascending water in the surrounding soil, a jointed pipe is introduced, which is usually formed of metal.

These wells have obtained the name of Artesian, from the attention that has been paid to their construction in the province of Artois, the ancient Artesium. The oldest Artesian well known to exist in France, to which at least any certain date can be fixed, is in the convent of the Chartreux at Lillers, in the department of the Straits of Calais, which is said to have been formed in the year 1126. Lillers is situated in the midst of an immense plain, where not the most insignificant hill is to be seen on any side. In this, and similar cases, we are led to inquire from whence are derived the elevated supplies of water, by the hydrostatic pressure of which, the water in the subterranean reservoir beneath the

plain, is caused to ascend to the surface. "They must sought," observes M. Arago, "if this be necessary, limits of view; at the distance of fifty, a hu hundred miles; or even yet farther." The subterranean sheet of water, three hundred miles by no means beyond the range of probability, so geological arrangement of the strata is conti stance which is observed frequently to occur extent of country.

Various Artesian wells have been formed in the London Basin; one of the earliest on record in this district, appears to be that situated in the grounds of Norland House, near Holland House, Kensington, which was made in 1744. It is, however, only within the last fifteen or twenty years, that the process of boring has been carried on to any extent in this locality; and several very important perpetual fountains have been formed during that period. Thus, in 1824, an Artesian well was formed in the grounds of the Bishop of London, at Fulham, near the river Thames. The bore was carried to the depth of 317 feet, passing through 250 feet of the tertiary beds of clay, and being continued for the additional 67 feet in the chalk. On reaching that depth, the subterranean sheet of water was met with, and the liquid accordingly immediately rose to the surface, the discharge being above fifty gallons per minute, or nearly forty thousand gallons daily; and in the season of drought which occurred in 1825, this valuable fountain continued to yield abundant supplies, when nearly all the other sources in the neighbourhood totally failed. Another Artesian well was formed in the garden of the Horticultural Society, at Chiswick, in which case the borings were carried to the depth of 329 feet; whilst in one which was made in the grounds of Sion House, belonging to the Duke of Northumberland, situated at no great distance from the latter place, but at a greater elevation, the borings were carried to the depth of 620 feet. In the latter case, the bore penetrated to a greater depth in the chalk, and must in all probability have entered a different sheet of water, for, notwithstanding the greater elevation of the

the lower greensand, there is every reason to suppose that we should arrive at a second vast reservoir. The great depth to which the bore must be carried to accomplish this, probably about 1200 feet, would, however, render this an undertaking of great expense and labour, and so long as abundant supplies are obtained from the chalk reservoir, the attempt is not likely to be made.

The supra-cretaceous, or tertiary strata, that is, all those formations which are situated above the chalk, constituting the plastic clay and London clay, do not, however, wholly consist of beds of impermeable clay, but in some parts present alternating beds of sand and gravel. In such cases, though on a comparatively small scale, internal sheets or reservoirs of water occur, which, like the vast reservoir accumulated beneath the London clay, are ready, as soon as an outlet is afforded them, to *spring* or rise up either to the surface, or within a greater or less distance from the surface, according to the elevation of the reservoir which forms their source. It is from such accumulations that the ordinary wells in the London Basin are supplied; but as these are smaller sheets of water, and are also more immediately dependent for their supplies, on the rain or snow which descends in the London Basin itself, they are liable to fall short, and even sometimes to fail altogether, after a long continuance of dry weather.

In some parts of France, the tertiary formations corresponding to those of the London Basin, not only contain a

greater number of alternating strata, but also are arranged in more extensive basin-shaped valleys; and in such localities, an admirable opportunity is afforded of observing the successive internal reservoirs of water, occurring at different depths. Some works were commenced near St. Nicholas d'Aliermont, a short distance from Dieppe, in search of coal. This search proved fruitless, but the boring brought to light the remarkable fact, that there existed in that locality, no less than seven successive large and abundant sheets of water at different depths. The respective depths were as follow:—

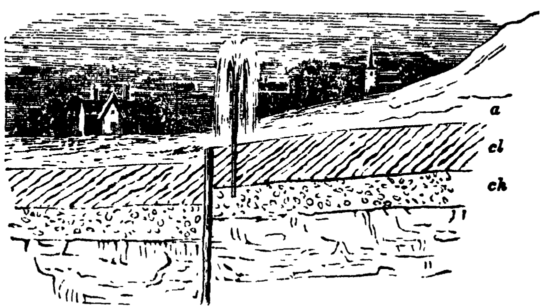
	Feet.
1st sheet, situated at about	90
2nd	328
3rd	580
4th	700
5th	820
6th	940
7th	1090

From all these sources the water rose to a considerable height, and the water from the seventh sheet, which, as we have seen, occurred at the depth of nearly 1100 feet, rose quite to the surface. Since the object of the search in this case was coal, and not water, the works were abandoned, but an immense Artesian well was thus undesignedly formed.

Artesian wells cannot be successfully formed in all situations; for it will be evident, that unless alternating layers of retentive and porous strata occur, internal reservoirs, if they exist at all, will only occupy occasional crevices and fissures, and consequently not give rise to copious springs or fountains. But it sometimes happens, that even in apparently favourable localities, borings for water are not attended with success. Thus, M. Arago mentions that a well was bored at Bethune, in the department of the Straits of Calais, which, after having been carried through seventy feet of earth of recent formation, and thirty feet of calcareous rock, brought to light a beautiful clear spring of water. In the garden of the contiguous proprietor, a similar attempt was made with full confidence of

success; but, notwithstanding the boring was continued to a much greater depth in the calcareous rock, it proved an entire failure, for not the slightest indication of water appeared.

To explain this apparently unaccountable difference, we may suppose, that between the first and second spot in which the borings were carried on, a dislocation, or shifting of the strata, had occurred, by which the continuity of the calcareous bed had been interrupted. Dislocations of this kind, which are by no means unfrequent in stratified rocks, are geologically termed *Faults*. These faults appear to be occasioned by some convulsion of nature, which has caused the disruption, or rending asunder, of the whole mass of strata, and the subsiding or sinking of the one portion, or else the upheaving or rising of the other; in consequence of which, not only are the strata not on the same level, but a fissure or crevice is formed, which not unfrequently becomes filled with clay, and thus effectually prevents the passage of the water from one portion to the other. By way of illustration, let us imagine two individuals placed in the situation of the landed proprietors at Bethune, supposing the one to reside on the right hand, in the accompanying diagram, and the other on the left. The first proprietor bores for water,



through the upper soil of recent formation *a*, and the London clay *cl*, into the chalk *ch*. The latter, being charged with water, and having a slight declivity towards this spot, a copious spring

gushes up, and since the supplying source has a considerable elevation above the surface, the Artesian fountain rises to an equivalent height above the ground, forming a perpetual jet d'eau. The proprietor on the left, being aware of the success which has attended his neighbour's attempt, determines to bore for water also on his estate, the surface of which consists of a stiff clayey soil, retaining the atmospheric water in little pools, and affording no good drinkable water. He accordingly bores into the same stratum, from which his neighbour had obtained a copious supply of excellent water; when, to his utter amazement as well as disappointment, not the smallest gush of water makes its appearance. He is at first quite at a loss to account for this difference, for he considers, that since both his and his neighbour's estates are situated on the declivity of the same basin-shaped valley, there would be every reason to expect that the same phenomena would present themselves; nay, since his land was lower than that of his neighbour, it might rather be supposed, if any difference existed, that the former would be more charged with water than the latter. He is also aware that an abundant natural spring rises at no great distance from the spot, in the grounds, perhaps, of a third proprietor. Desirous of ascertaining the cause of this apparent anomaly, he has recourse to geological investigation, when the whole mystery is at once unravelled, by the discovery that a fault occurs at the line of junction, between his and his neighbour's estate. The fissure caused by the fault has been entirely filled up by clay, in consequence of which the water pouring down from above cannot pass that barrier; though, at some little distance off, in the line of the fault, it meets with an outlet, and gushes forth in a natural spring. He thus perceives, that an Artesian well, formed on the upper side of the fault, would produce a copious supply of water, whereas, if a bore be carried into the chalk below that line, not a drop of water might be found to rise to the surface; for the latter portion being effectually debarred from receiving any supplies of rain and snow, by the superincumbent bed of clay, and bounded on the upper side by the clay-lined fault, no water can accumulate in the interior. And even such

small portions of water as might find their way through crevices into the chalk, would, on account of the sloping direction of the strata, drain or flow off from thence to the lower parts of the basin.

We have dwelt at greater length on this subject, because the circumstance of faults or fissures occurring in the earth, filled with clay, or other impervious materials, and thus arresting the progress of subterranean waters, not only affords an explanation of the differences occasionally observed in boring for Artesian wells, but also of many of the phenomena of springs, to which we shall direct our attention in a future page.

The practical utility of Artesian wells has been more especially experienced in various flat districts, where good water could not be obtained from wells near the surface. Thus, in the low coast districts of British Guiana, the upper springs are all brackish, and the inhabitants were, until very lately, dependent on the rains for their supplies of water, and consequently were liable to suffer much from scarcity of that important article, during the dry season, at which period no rain falls for three months. Artesian wells have, however, been sunk, and an abundant supply of excellent water obtained, by which means that rich and fertile tract has been rendered far more healthy and fit for man's abode. For instances of the great benefit derived from Artesian wells in flat and marshy districts, we need not, however, have recourse to distant regions of the globe, for our own country will afford us abundant evidence of this fact. Thus, in the neighbourhood of Louth, in Lincolnshire, no springs of drinkable water existed, until it was discovered, that by boring through the upper stratum of clay into the subjacent chalk, good water might be obtained. Artesian wells, locally called "blow-wells," were therefore constructed, and an abundant supply has thus been obtained, rising incessantly to the height of several feet above the surface.

But perhaps there is no part of the world where Artesian wells are more useful, or more general, than in Essex. Not only in the marshes, but also along the coast of that county,

as well as in the islands belonging to it, these wells have proved of the greatest utility and importance. Formerly, in some seasons, the ditches or channels of water were quite dried up, so that the fish perished, and the cattle suffered so severely for want of water, that the farmers sustained very great losses in their stock. But now, by the aid of Artesian wells, the ditches are kept full all the year round, and the farmers and landlords greatly benefitted accordingly. Thus, in Foulness Island, there are no natural springs, and until lately, no water (except atmospheric, which was collected in ponds and ditches,) was to be met with. In hot weather, this water, stagnating in these receptacles, became most offensive; notwithstanding which, the inhabitants and the cattle were compelled by necessity to partake of it as long as it lasted, and when this wretched beverage failed altogether, scanty supplies were obtained at the eastern extremity of the island, a distance of seven miles. It will readily be imagined that such unwholesome water must have proved highly detrimental to the health of the inhabitants. Artesian wells have, however, been formed, and an abundant supply of good water obtained, by which the whole condition of the island has been improved.

In desert tracts, again, which, owing to the deficiency of water, scarcely afford even a passage for man, and much less a residence, the benefit that might accrue from the introduction of Artesian wells is almost beyond calculation. An instance of this is afforded by the successful borings for water in the desert between Kahiro and Suez, an important tract, on account of its forming part of the most frequented overland route to India, and where several Artesian wells have been constructed, under the management of some English engineers. Perhaps no mode that man could devise, would be more likely to change the climate, and alter the conditions of the arid Sahrà or Great Desert of Africa, than the introduction of a number of Artesian wells into that sandy waste. Nor, indeed, does it seem that this would be altogether a novel method of rendering some portion of that district fertile, for, according to a passage cited by M. Arago, from Dr. Shaw, who visited those regions in the begin-

ning of the last century, Artesian wells, though not known under that appellation, were met with in the Great African Desert itself. "Waol-reog," says Dr. Shaw, "consists of a cluster of villages, situated some distance in the Sahrà. These villages have neither springs nor fountains, but the inhabitants procure water in a very extraordinary manner. They dig wells to the depth, sometimes of 600 feet, and sometimes even of 1200 feet, and they never fail at that depth to meet with water in great abundance."

Nor does it appear that the construction of these wells in the wadys or oases of Northern Africa, has been confined to this comparatively modern era: for M. Arago further mentions, that Niebuhr cites a passage from Olympiodorus, who flourished at Alexandria about the middle of the sixth century, in which it is stated, that when wells are dug in the oases to the depth of 600, 900, or sometimes 1500 feet, rivers of water gush out, of which the agriculturists take advantage to irrigate their fields. And perhaps, we may not greatly err, if we consider the "wells of springing water," dug by Isaac in the land of Gerar*, were, in fact, Artesian wells, or fountains. In that early age, the execution of such a work would be an undertaking of no trifling importance; and the possession of such a well, might very probably give rise to contention, as recorded in the history of that patriarch.

The Chinese are said to have practised this mode of obtaining water for thousands of years; and, perhaps, we may not without reason, suppose that it has been very long known to that remarkably precocious people: and indeed, the Chinese borers of the present day appear to be singularly expert in performing this operation, sometimes carrying the bore down to the depth of 2000 or even 3000 feet: a depth scarcely equalled, perhaps, by any European Artesian fountain.

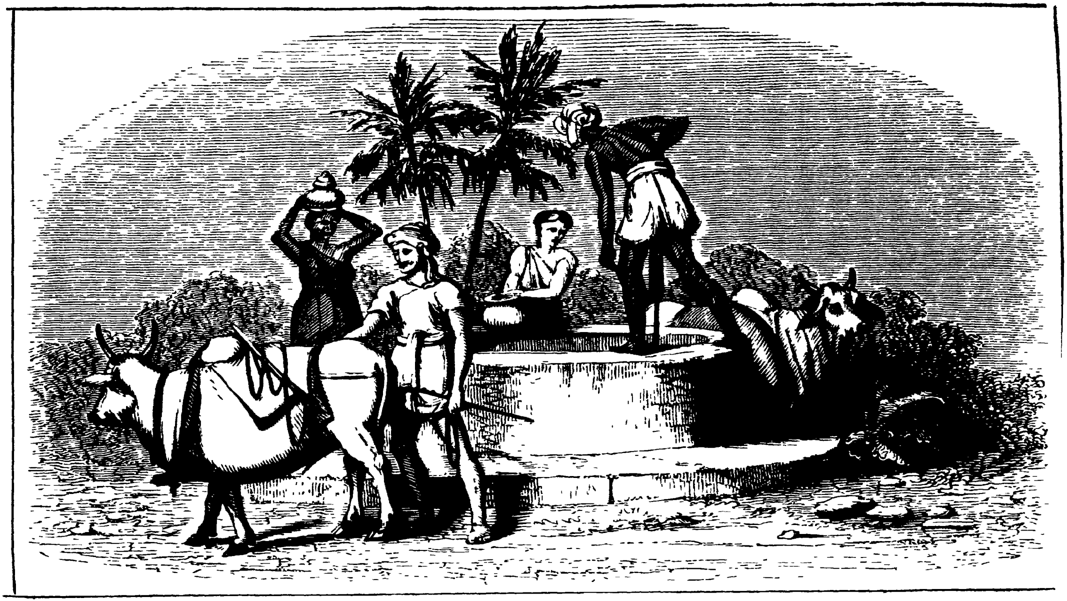
* Genesis xxvi.

CHAPTER VIII.

HYDRAULIC ENGINES.

THE artificial modes of producing motion in water by mechanical means, may be considered as forming a second division of hydraulics. This comprises an account of the various pumps and engines which have been employed to raise water, and thus overcome its natural equilibrium—a branch of our subject which is of the greatest practical utility. It is not, however, our intention to enter at great length on this portion of hydraulics; but a brief description of some of the principal machines invented for this purpose, and their mode of use, cannot be devoid of interest.

The simplest hydraulic engines are those by which water is raised by the mere exertion of manual labour, or of some mechanical means. Probably the first hydraulic machine consisted of the common bucket and rope as used at our common draw-wells, either raised by hands, or drawn up by means of a windlass. In the earliest periods, water seems to have been procured by simply dipping an earthen pitcher or jar into the well, which latter, perhaps, may only have consisted of a tank or basin, erected to receive the waters of a natural spring, issuing at the surface of the ground; the tank being provided with an outlet to carry off the superfluous waters. Wells of this description are frequently approached by steps; and such, probably, was the construction of the well from which Rebekah drew water in her pitcher for the use of Eliezer, Abraham's steward. Women of the first distinction continue to the present day to perform the office of drawers of water from the public wells in many parts of India. They fetch it in earthen jars, which are usually borne on the head, sometimes two or three jars being thus carried at once, forming a sort of column on the bearer's head; and as the utmost steadiness is required to bear these securely, the habit of carrying water imparts to the females of those countries a singularly erect and stately air.



Water-Carriers of the East

Among the Arabs, water is more usually drawn from the wells in leathern buckets, by means of a rope; and this office also devolves exclusively on the women, all ranks participating in the employment. In Turkey and Persia, however, women of condition no longer perform this service, and the office of water-carriers is now in great part fulfilled by men in those countries.

This mode of raising water, however, could not be otherwise than tedious, though the supplies thus obtained might suffice, when the liquid was chiefly required as a beverage, and this in countries where, owing to its comparative scarcity, it was used sparingly. The inhabitants of these districts, in the more early ages, were also, if not nomadic or wandering tribes, principally occupied in pastoral pursuits, and gave little or no attention to agriculture. When, however, the progress of civilization led to the cultivation of the earth, an extended supply of water became an object of paramount importance; and the peculiar character of Eastern countries led to the introduction of artificial irrigation. Probably the earliest modes of effecting this, were laborious and troublesome, and may not have differed greatly from the manner in which this operation is at present carried on in some parts of India.

Thus, Colonel Sykes mentions that he observed the following simple method of watering a field near the village of Piroorgool, in the Dukhun (or Deccan):—The bed of a rivulet with very low banks, having been artificially dammed up, three pieces of wood, like a gin or trap, were placed over the water, a scoop being suspended by a rope to the top of the gin, whilst a man was employed to scoop the water from the rivulet into his field. The labour was very great, and, as may be supposed, the supply of water small. In other parts of the same region, irrigation is effected by conducting water in streamlets from running rivers or brooks, over the land to be watered; but the latter process is only available where the river is on a higher level than the land to be irrigated; and the supplies are liable to fail in the hot season. In other districts, recourse is had to drawing water from wells for

watering the ground. In the latter case cattle are employed, being attached to the rope from which the bucket is suspended. The animals pull down an inclined plane, and the water being discharged from the bucket, they readily walk backwards up the plane to the highest point, and on the bucket being again re-filled, they once more descend the inclined plane. The driver meanwhile sits on the rope singing to the cattle. Colonel Sykes, in speaking of this mode of irrigation in the Dukhun, mentions that there is a singular uniformity of time between the delivery of two buckets, the interval seldom exceeding seventy seconds; and, that a man with a pair of bullocks, working for seven hours, may draw up about twenty thousand gallons of water per day.

In the Monghere districts of Bengal, the following mode of irrigation is practised. A deep well is dug in the highest part of a field; the latter, having been ploughed, and prepared for cultivation, is then divided into little square compartments, or plots, separated from each other by trenches or dykes which are designed to convey the water over the field. Each of the little compartments is further surrounded by a small embankment, about four inches in height, formed of clay or some material capable of retaining water. The water is then raised from the well at the upper part of the field, in leathern bags or buckets, by means of two bullocks yoked to a rope, and is poured into the trenches, from whence it is conveyed into the plots, being allowed to remain in the latter, until the soil appears to be sufficiently saturated with moisture, when the remaining portion is drained off, and conveyed to another plot; the process being continued until the whole field is irrigated.

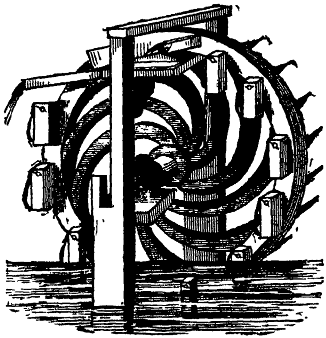
Among *hydraulic machines*, perhaps, the earliest may not have been dissimilar to those represented on some of the Egyptian monuments, which consisted simply of a rude lever, attached to posts or pillars, formed either of wood, of canes, or of mud, and having a stone or lump of mud, at one end, sufficiently ponderous to outweigh a bucket or vessel filled with water, suspended at the other end, and thus, by the excess of weight of

the former, raising the latter to the height of the trough into which it is to be emptied. The labour of the person engaged in the operation, is thus confined to the act of emptying the bucket into the trough, and of pulling it down to the well, when empty.

This simple hydraulic machine, under the name of the *shadoof*, is still much used in Egypt. The posts or pillars which form the frame-work, are usually about five feet in height, and from two to three feet apart: a piece of wood or cane extends horozontally from the top; and to this is suspended a slender lever, formed of a branch of a tree, having at one end a weight chiefly composed of mud, and at the other a vessel in the form of a bowl, made of basket-work, or of a hoop and piece of woollen stuff or leather. With this vessel the water is thrown up to the height of about eight feet, into a trough hollowed out for its reception. When it is required to raise the water to a greater height, a series of four or five shadoofs may be employed. In the latter case, the water being first raised from the river or lake by means of shadoofs, is discharged into a trough, from whence it is again raised by a second row of shadoofs, and discharged into a second trough at a higher level; and so on from trough to trough, until it has been raised to the required elevation.

The hydraulic machine, usually called the *Persian wheel*, appears also to have been introduced at a very early period, and like the preceding machine, various modified forms of the Persian wheel are much employed in all the principal streams of Western Asia, as well as among the Chinese, for the purpose of irrigation. The simplest form of the Persian wheel consists of a circle or rim of wood, supported by arms or spokes from the central axis, and which revolves in a vertical or upright direction. This wheel is partly immersed in the water; whilst to the rim, or outer circle are attached a number of buckets, or, in some cases, of earthen vessels, by means either of iron hoops, or of cords. As the wheel revolves on its axis, these buckets necessarily dip in succession under water, and, being filled, are raised in an upright posture to the highest point of the wheel, in a conti-

nuous series; they then, as the wheel moves onward, turn over, and empty their contents into troughs prepared to receive the water. Motion may be given to this wheel, either by the



Persian Wheel.

power of animals, or that of water: for, if the machine be employed in a running stream, where there is sufficient water to spare, the wheel may be provided with *vanes*, or float-boards, similar to those affixed to any other water-mill, and in that case, the force of the running water will both turn the wheel, and raise the water into the trough. This machine, if thus worked, requires no care or attendance whilst in operation, and as the motion is uninterrupted so long as the stream continues to flow, it will raise a considerable quantity of water, even though the buckets may be of small dimensions. When a river or stream has not sufficient force to turn the wheel, or when the water has to be drawn from a well, a second wheel with cogs is fixed to the same axis, and the latter is acted upon by a third wheel, also cogged, which is placed horizontally, and is turned by a pair of bullocks, or by a single bullock, according to the force required; that, of course, being dependant on the size of the machine. The construction of the Persian wheel is generally of a very rude kind; nor, indeed, does this machine require any of the nicety in its structure which is usually necessary in mill-work, but will

act, even though made in the roughest manner. The importance of such easily-constructed machines is very great in warm climates, where rain is periodical, and where, if not well supplied with water, the parched and thirsty ground will yield little or no produce; but where vegetation flourishes in the utmost luxuriance, when the high temperature is accompanied by abundant supplies of moisture. In such regions, irrigation becomes most essential; and it is by paying attention to this process, that the vast fields of wheat are produced, which the late Sir Alexander Burnes mentions, as extending, without interruption, from Ajmere to the Runn. The river Loonee, which rises in the mountains of Ajmere, traverses this territory, and by the waters of that stream, the whole district is irrigated, and rendered thus remarkable for its fertility. "The water," says Sir A. Burnes, "is generally raised by means of the Persian wheel, which is of the rudest manufacture, but has, nevertheless, decided advantages over the leathern bag, not the least, in the saving of labour. It is distributed over the fields by means of aqueducts of earth, which sometimes extend for a mile in length, and are constructed with care and due attention to the level of the country; and the fields are surrounded with dykes to prevent its egress. The wheat is sown after the rainy season has terminated, and is reaped in March. It does not require more than six waterings to bring it to maturity; but these are most copious, for the labour of a pair of oxen will only saturate a beega (twenty fathoms square) of land, in twenty-four hours."

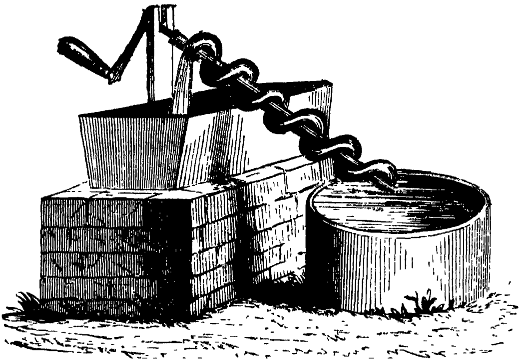
The Persian wheel is, and has long been employed for similar purposes on the borders of the river Euphrates. "The reason why these water-wheels are so much in use," observes Rauwolf, (an old author, cited by Colonel Chesney,) "is because this river doth not overflow as the river Nile, to water the grounds, neither doth it rain enough here sufficiently to moisten the seeds and garden plants, that they may not be burnt by the great heat of the sun, wherefore they must look out for such means as will supply their want. To do this, they erect water-wheels in the river, which go night and day,

and dip up water out of the river, which is emptied into peculiar channels that are prepared on purpose to water all the ground." Erections of this kind, indeed, appear to be of far more ancient date than that of the author just cited, for Colonel Chesney noticed near Hît, on the river Euphrates, numerous remains of very ancient water-wheels and aqueducts, designed for irrigating the country, some of which are still used, both for that purpose, and also for grinding corn. The aqueducts diverge at right angles from the river, some of them running inland for the distance of between 3000 and 4000 feet. The wheels are about thirty-three feet in diameter; and earthen vessels, about twenty inches deep, and three or four inches in diameter, perform the office of buckets, differing, however, from the usual arrangement of the latter, in being fixed, instead of moveable, and having their mouths or apertures, turned towards the water, by which means the wheel is also turned on its axis; whilst, instead of the float-boards ordinarily made use of in the Persian wheel, the fronds or leaves of palm-trees are adopted for that purpose.

Artificial irrigation is comparatively little practised in the British Isles; for, owing to the humidity of the climate, it is not generally required. In some particular kinds of soil, it has, however, been employed with extreme advantage, converting many an acre of barren heath land into valuable pasture. It has also been successfully applied for the improvement of peat-bogs, when the latter occupy elevated situations. This process is effected by causing a stream of water to flow through such a plot of ground; for, in that case, the running water appears to check the growth of bog-plants, and to promote the rapid growth of wholesome grass, which immediately springs up on its banks. This has been proved by experience in many parts of Scotland, and also, in some few instances, in Ireland. It is, however, only applicable to mountain bogs.

The hydraulic machine called the *Screw of Archimedes* is so named from its form, which is spiral, or screw-like, and from its having been the invention of the celebrated Syracusan

mathematician, Archimedes, by whom it was employed for raising water, and for draining land in Egypt, about two

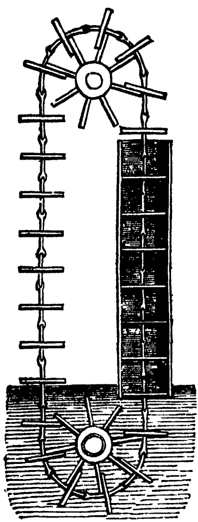


Screw of Archimedes.

hundred years before the Christian era. This machine acts upon the same principle as the Persian wheel, that is to say, a series of receptacles for water dip in succession into the water, where they become filled, and are carried up in a continued series; but, instead of being placed on the rim of a wheel, and being separate and detached like the buckets or vessels in the Persian wheel, the receptacles in the screw of Archimedes, are formed by the whorls of a flexible tube or pipe, and they are raised, and the succession effected, by turning the whorl, or screw. To accomplish this, the pipe, which is formed of leather, is wound in a spiral form round a solid cylinder, the two ends of which are furnished with pivots, so that the cylinder may be made to revolve by any power applied either to its upper or lower extremity. This apparatus must then be supported in an inclined position, as represented in the cut; and having its lower end immersed in water, and the upper end so placed as to discharge its contents into a cistern or reservoir, it is turned on its pivots, and the water forced up through the pipe, regularly advancing with each turn of the screw. The water is thus forced up an inclined

plane; and from its form, this machine may be advantageously applied in some situations where the Persian wheel cannot be employed, on account of a deficiency in the depth of water, and other causes. The Archimedean screw is, however, very subject to become choked up by sand, mud, and weeds.

The *chain pump* is little more than a modification of the preceding machines. This apparatus consists of a number of flat plates, formed of wood or metal, usually square, and connected together by an iron rod, having joints between each board, so as nearly to resemble a chain; the whole series, or *chain*, of plates being supported, and kept in its place, by two wheels, which are provided with arms to catch and support the plates in succession, as they come in contact with the wheels. The upper wheel is turned by means of a winch, and as each plate in succession passes the arms of the wheel, the whole chain of plates moves onwards, one side passing in a downward direction, and the other ascending. In order to render this chain of plates available for raising water, the ascending side is made to pass through a square box, or hollow trunk, which fits closely to the plates, and thus forms the pump. The lower wheel, as well as the lower end of the box, must be under water, and the chain of plates passing upwards through this box, produces a succession of chambers or cavities, which become filled with water, and which, when they are all filled, eventually empty themselves at the top. It will be evident that this machine can only work in water of a sufficient depth, but it has the advantage of not being liable to become choked, and will even force up mud, stones, and weeds, as well as other

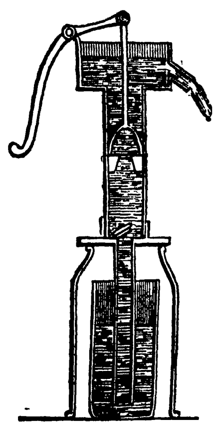


Chain Pump.

substances, which would entirely impede the operations of a more delicately-formed machine; and the chain pump is therefore usually employed in draining the water for the purpose of laying the foundations in the construction of bridges, docks, and similar works on a large scale.

The second class of hydraulic machines comprises those in which water is raised by *the pressure of the atmosphere*, and includes all the machines to which the term *pump* is more especially applied. These machines act wholly on the principle of removing the pressure of the atmosphere from the surface of the water in the machine, which may by this means be raised to the average height of about thirty-two feet; though, since the pressure of the atmosphere is variable, this is also liable to some variations, as will be indicated by the mercury in the barometer; for the atmospheric pressure is greater when that stands at 30°, than when at 29°; and consequently, the operation of raising water by means of this description of pump, will be less laborious in fine dry weather, than in moist or stormy weather.

There are several varieties of pumps; but the simplest, and that most commonly used, is the ordinary *lift*, or *household pump*. This useful machine is of great antiquity, its invention being ascribed to Ctesibus, of whom we have already heard, when speaking of the clepsydra. But, although this application of atmospheric pressure was made at that period, there is much reason to suppose, that the principle of its action was not understood until long afterwards. The common pump consists of a barrel or hollow cylinder of metal, very truly bored, and furnished with a piston, made to fit air-tight in this cylinder; and the piston is usually moved upwards by means of a lever, which, in common parlance, is called the handle of the pump.



Lift Pump.

The cylinder, or barrel of the pump, being once filled with water to the level of the piston, every time the latter is raised, a vacuum is formed between that and the surface of the water, so that there is no atmospheric pressure on the water within the barrel of the pump; but, since the atmosphere still continues to press on the surface of the water in the reservoir, or well, by which it is supplied, the force exercised by the latter causes the water in the barrel to be pushed or driven upwards to a height corresponding to the pressure of the atmosphere, that is, to the average height of about thirty-two feet. In the centre of the piston, a valve is fixed, which is forced open by the pressure of the water when moving in an upward direction, but firmly closed by its pressure in a downward direction, so that it allows the water to pass upwards, but prevents it from passing downwards. When the piston is lowered, (which is done by raising the handle of the pump,) the water being pressed upwards with the force incident to atmospheric pressure, passes through this valve, and thus the portion of the barrel above the piston becomes charged with water, which, the next time the piston is raised by the action of the lever, (that is, by pressing down the handle of the pump,) is forced through the spout of the pump.

The *forcing pump*, which is a machine of very general application, consists, like the common pump, of a cylinder and piston; but in the forcing pump, the piston, instead of being furnished with a valve to admit the upward passage of the water, is solid: whilst the cylinder is provided with a lateral pipe, through which the water is to be forced into the working barrel, the entrance into the latter being furnished with a valve that prevents the water from returning again, and consequently, it will be constrained to find its way up the pipe, which may be extended to a considerable height. For, since in this operation, the ascent of the water does not depend on the pressure of the atmosphere, but on the degree of mechanical force applied to the handle of the pump, water may by this means be raised to any required height, without regard to atmospheric pressure.

When any degree of force is to be exerted for the purpose of imparting motion to a body previously in a state of *inertia*, or rest, the power required for giving the first *momentum*, or impetus, is considerably greater than that required for maintaining the body in motion when once imparted to it; and in machines constructed on the principle of the forcing pump, a fresh impetus would be called for, every time the handle was moved, which would cause a considerable waste of power. This objection is in some measure obviated by the use of an *air-vessel*. In the usual construction of the forcing pump, therefore, the upper pipe passes through a hollow vessel, to the top of which it is fixed; but the upper pipe, although it extends to within a short distance of the lower pipe, does not quite meet the latter. The lower pipe is also of larger dimensions than the upper pipe; the consequence of which is, that every time the piston is moved, a certain quantity of the water is thrown into the air-vessel, and not finding sufficient space to escape along the upper pipe, it remains in that vessel. Air, being lighter than water, necessarily occupies the upper part of the air-vessel, and being now confined by the water, it cannot escape; but, being elastic, it becomes condensed or compressed into a smaller compass than it would naturally occupy, in order to make room for the water. When the mechanical force is again applied to the pump, the elastic air, instantaneously springing to its natural dimensions, has time to expand, and thus to force a certain portion of the water into the upper pipe; by which means the water is maintained in a state of activity; and no new impetus is required to set it in motion, which otherwise, as we have already said, would have been required at every stroke of the handle.

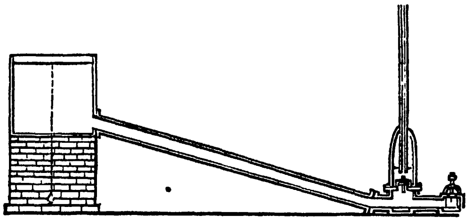
In a contrivance so simple, and at the same time producing such beneficial effects in a machine of such great importance and utility as the forcing pump, we cannot but be forcibly struck with the example it presents of the advantages which result from the pursuit of science; for, without some acquaintance with the properties of air, the elasticity of which, in this instance, we find actually applied

to a practical use, this important improvement could not have been made.

Various modifications and improvements of these pumps have been made, but the principle is the same in all. The mining districts of this country contain a greater variety of pump machinery, than is to be found in any other part of the world. Vast mains of cast iron are seen in constant operation, "delivering their fluid contents, with a degree of precision, equal to that displayed by the arterial tubes of the human body." Great attention is also paid to the construction of pumps for nautical purposes; and many improvements have been proposed, the chief objects of which are, to prevent the valves from being choked up with mud, sand, sea-weed, &c., and to lessen the labour of working the pumps.

The fire-engine is very similar to the double ship's pump, and consists of two forcing pumps working into one common air-vessel. This engine has been in use for more than a century; but a great improvement has, within a few years, been made by Mr. Braithwaite, which consists of a portable steam-engine attached to the apparatus, and which is employed to impart motion to the pump-rod or handle: and thus, not only is the action of the fire-engine more effectively performed than by the firemen, but much risk of life avoided. And since the steam is prepared during the passage of the machine to its place of destination, no loss of time occurs on that account, and this engine forms an exceedingly powerful and efficient apparatus.

The machine called the *water ram*, or the *hydraulic ram*, is another very valuable instrument for raising water. The action of this machine depends on the *momentum*, or new energy, which descending water acquires, by being put in motion for a short time, and then stopped. It may have been observed, that on turning a cock attached to a pipe connected with an elevated cistern, the water flows with great violence; and that, on shutting off the water suddenly, a concussion is felt. So great indeed is this shock, that not unfrequently the pipe is burst



. Hydraulic Ram.

open near its extremity. This circumstance arises from the effort made by the water to escape; and when thus suddenly arrested in its progress, it pushes with the whole force of the descending column of the water against this portion of the pipe; and as this will be in proportion to the height of the supplying cistern, therefore, if the latter should occupy an elevated position, the concussion thus caused may burst the pipe, unless a proper outlet for the water be provided.

This effect was experienced in a remarkable manner in a hospital at Bristol, where a leaden pipe had been laid for the purpose of conveying water from an upper floor of the building to the kitchen below, when it was found that almost every time the cock was made use of, the pipe was burst at its lower end. After many unsuccessful attempts to remedy this evil, it was at last determined to solder a small pipe into the main pipe, immediately behind the cock, by which means a small portion of the water might be carried off: and in order to prevent the water running to waste, this auxiliary pipe was carried to the same height as the supplying cistern; it being supposed, that on hydrostatic principles, the water would rise to the same level as that in the cistern, and no higher. By this means the evil was remedied; for, on shutting the cock, the pipe did not burst as before, but a new and unexpected phenomenon presented itself: a jet of water of considerable height being forced from the upper end of the auxiliary pipe. It became necessary, therefore, if possible, to overcome this jet; to effect which, the length of the auxiliary pipe was increased, and carried to the

top of the building, which gave it twice the height of the descent of the water from the cistern to the lower extremity of the first pipe,—that is to say, twice the height of the column of water,—when, to the no small surprise of those employed in constructing the work, the jet of water even at this height still made its appearance, though in diminished volume. A cistern was accordingly placed at the top of the house, to receive this superfluous water, which was thus raised to that elevation, and a supply obtained for the upper apartments of the establishment, without trouble or exertion of any kind.

It is on the principle above described, that the water ram is constructed; but it will be evident that it is capable of application only in situations where a descent of water from an elevated source, either natural or artificial, can be obtained, and is therefore not available in all situations. The simplicity and cheapness of its construction, and the circumstance of its requiring no attendance after it is once adjusted and set in action, render it, however, peculiarly applicable for the supply of houses, fountains, or pleasure grounds, situated in the vicinity of mountain torrents, or elevated springs.

The mode in which the water ram is constructed is as follows:—A pipe of wood or iron, from eighteen to twenty, or even forty feet in length, is laid in a sloping direction from the spring-head or reservoir, to the lowest depth which local circumstances will permit, which may be from one foot to six or eight feet below the supplying reservoir, though, of course, the force with which the water passes will increase with the elevation. The pipe is terminated in a straight branch, closed at the end, so that the water cannot find a passage out in that direction; but near the end an orifice is made in its upper surface, from whence the water is permitted to escape, not, however, uninterruptedly, a valve being fitted on the inside of this orifice, which is so adjusted that whilst the water is motionless, or only moving slowly, it sinks by its own weight in the water, by which means an outlet is afforded for the liquid; but, if moving with any degree of rapidity, its force will be more than equal to the weight of the valve, which it

will therefore push or lift up; and thus, the orifice being closed, the passage of the water will be suddenly and completely stopped. Checked in its onward course, the water, rushing with greater or less rapidity according to the elevation of the source from whence it flows, strives with all its might to find an outlet, and if none were provided, would burst the pipe, as in the instance already related at the Infirmary at Bristol. Between the orifice and the end of the sloping portion of the pipe, a second orifice is formed, which communicates with another pipe placed in a vertical position, and through which the water is thrown to the required elevation.

The blow, or shock, which the water gives when thus suddenly checked in its progress, is so violent that it is driven back by its own force, and this to so great a degree, that it not only rushes up the vertical pipe, but also makes an effort to re-ascend the sloping pipe by which it had descended; and thus a temporary quiet ensues at the terminal orifice, so that the valve again sinks in the water, and the orifice is again opened, permitting once more the free escape of the liquid at the lower extremity of the machine, until another rush of water closes the valve, and the water is again forced upwards. And thus a new momentum, or impetus, is again and again imparted; so that the action of the machine continues unceasingly, without any external aid, as long as it is supplied with water, and remains in repair. A machine of this kind has been constructed, which furnished a hundred hogsheads of water in twenty-four hours, to the height of a hundred and thirty-four feet perpendicular. It has obtained its name from the force with which the water pushes, in a manner not very dissimilar to that of a battering ram.

CHAPTER IX.

WATER-WHEELS.

The hydraulic engines which have hitherto engaged our attention consist of such as are designed to raise water above its level. Let us now give some consideration to another branch of hydraulics, namely, the power of water in moving machinery, and the means of obtaining, and using to advantage, the power and motion thus acquired.

> Where tumbling waters turn enormous wheels,
> And hammers, rising and descending, learn
> To emulate the industry of man.

This branch of our subject will include a brief notice of the various water-wheels, or mills, by which motion is given to machinery,—a portion of our present inquiry by no means inferior to the preceding in practical utility, and which is unquestionably far more associated with rural scenery and poetical description, than any other branch of machinery. It is true Wordsworth has celebrated in song the "old iron-bound bucket" of his paternal residence:—

> When, dripping with coolness, it rose from the well,
> The old oaken bucket, the iron-bound bucket,
> The moss-covered bucket that hung in the well.

Pumps, however, and Persian wheels, and hydraulic rams, are, without doubt, far more adapted for practical service, than for embellishments to adorn the canvas of the painter, and the page of the poet. And thus we find that Pope, when alluding to the pump erected in the market-place of Ross, in Herefordshire, by the justly renowned John Kyrle, the "Man of Ross," cannot admit so unpoetical a term into his verse, but celebrates it in the following manner:—

> From the dry rock, who bade the waters flow?
> Not to the skies in useless columns tost,
> Or in proud falls magnificently lost;
> But clear and artless, pouring through the plain,
> Health to the sick, and solace to the swain.

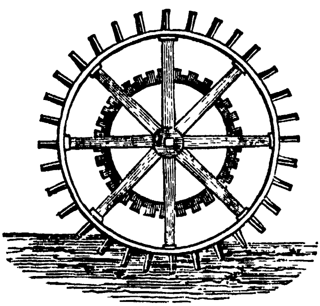
But if we turn to water-mills, where, we may almost ask, where is the landscape painter who has not, at some period of his career, delineated these picturesque objects? where the poet who has not sung of water-mills?

> Mine be a cot beside a hill:
> A bee-hive's hum shall soothe mine ear;
> A willowy brook that turns a mill,
> With many a fall shall linger near.

To return, however, to the more practical part of our subject, namely, the use of water as an impelling power, and the methods most usually employed of applying this liquid as a mechanical agent.

The water-wheel, which may, perhaps, be considered as the most important of all hydraulic machines, acts either by the direct impulse, or by the weight of the fluid by which it is propelled. All water-wheels consist of a hollow cylinder or drum, revolving on a central axle-tree or spindle, the latter being placed in communication with the machinery to be put in motion.

The most simple, and probably most ancient form of water-wheel applied for propelling machinery, is that called the *undershot*, *tide*, or *stream-wheel.*



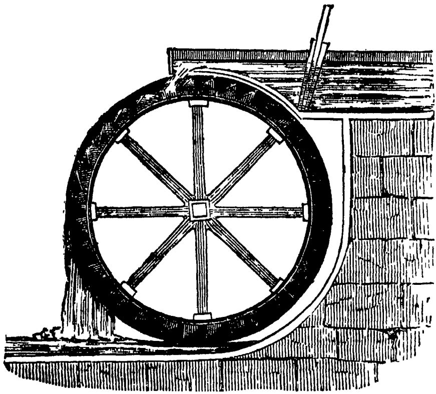
Undershot Water-wheel.

This consists of a series of float-boards, arranged like rays round the periphery, or outer circle of the wheel, the latter

being moved by the force of the water acting against these float-boards. This kind of wheel is particularly adapted for use in tidal rivers, where the current sometimes flows in one direction, and at others in an opposite course; for, owing to the regular arrangement of its float-boards, the water will act equally well in either direction; but it can only be employed to advantage in situations where there is a profusion of water always in motion. As, however, it does not require any great fall of water, it is more applicable than any other kind of water-wheel to streams in their natural state. Water-wheels of this kind are described as being very numerous on the river Danube, where they are applied to the purpose of grinding corn. "Below Buda and Pesth," observes a recent traveller, "one is struck by the curious flour-mills of the Danube, which consist of a wooden house, erected in a large unwieldy boat, moored near the most rapid part of the stream. Parallel to this, and only a few paces distant, is fixed a smaller boat, the heads of both being directed down the stream. Between them is suspended a water-wheel, which, of course, revolves rapidly with the flow of the river. Ten or twenty of these are sometimes found in succession."

The *overshot water-wheel*, instead of being propelled like the undershot wheel, by the impulse communicated by a flowing stream, owes its action to the weight, or downward pressure of a body of water pouring from a higher level than that of the wheel. This water-wheel will produce far greater power with a much smaller supply of water than the undershot water-wheel, but it requires a considerable fall in the stream in which it is placed, and, consequently, is by no means so available as that machine, in all situations: for, to set this in motion, either the stream must dash down in the form of a rapid, or cascade, or be artificially pent up, immediately above the water-wheel; unless, indeed, that ingenious contrivance, the canal-lock, be resorted to. In the construction of the overshot water-wheel, in place of the float-boards, a series of narrow troughs or cells are fixed round the outer circumference of the

wheel, across the whole width of which they extend. The water is then conducted by a level channel of higher elevation than the wheel, so as to discharge itself into the troughs or recepta-



Overshot Water-wheel

cles. When these are filled, the gravity or weight of the water bears them down, thus causing the wheel to revolve on its axis; and the troughs are so constructed, that they retain their liquid contents until they reach a certain point, when they discharge the water into the lower stream, which is commonly designated as the *tail stream.* As the wheel continues to revolve, these troughs are carried up empty, and ready to be replenished when they once more arrive in contact with the supplying stream of water. If the water were suffered to flow into these troughs with too great force and rapidity, it would splash out, instead of filling them, and would, therefore, pour over the surface of the wheel, without producing its proper effect. To prevent this, the water is seldom permitted to run upon the wheel in a stream of more than from half an inch to an inch in depth, and when well-regulated, there is scarcely a drop of water wasted.

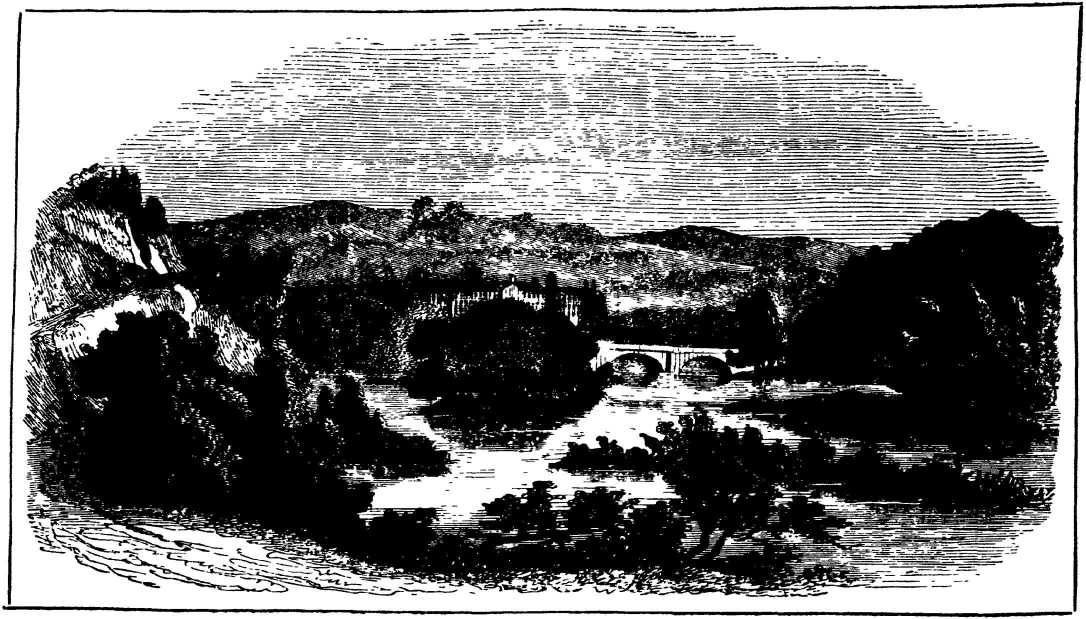
The *breast water-wheel* may be considered as partaking of the character of both the undershot and overshot water-wheels.

In the breast-wheel, the water, instead of passing over the top of the wheel, as in the overshot-wheel, or beneath it, as in the undershot-wheel, pours from a channel nearly half-way up the wheel, that is, rather below the level of its axis. Instead of troughs it is furnished with float-boards, like the undershot water-wheel; and the water pouring from the raised channel on these float-boards, the breast-wheel is impelled, not only by the gravity of the water, but also by its impetus, or moving force. In the breast-wheel, the brickwork which forms the channel for the water, is built in a circular form, and of a width so as to make it parallel with the exterior edges of the float-boards, or extreme breadth of the wheel, this being made as close as circumstances will admit, in order to avoid as much as possible the escape of the water, but this form of wheel must always be attended with some waste of water, however perfect the workmanship.

In order to allow any of the above water-wheels to work with freedom, and consequently to the greatest advantage, it is absolutely essential that the *tail water*, as it is called, or that which pours from the wheel after it has performed its office, should have an uninterrupted passage to make its escape; for, whenever this is not the case, it accumulates, and offers a resistance to the float-boards, and thus considerably abstracts from the power and velocity of the wheel; sometimes, indeed, to so great an extent, as altogether to hinder its working.

The three descriptions of water-wheels above-mentioned, are the only ones generally admitted into practice, and they do not allow of much improvement, since the principles on which water-wheels act must always remain the same. The breast-wheel is by far the most extensively used; but it is, in effect, vastly inferior to the overshot-wheel, in proportion to the quantity of water employed; a circumstance partly arising from the unavoidable waste of the liquid, and partly from the lesser elevation at which the water is supplied, and the consequent smaller force of the descending column of water.

Although water-mills appear to have been unknown in England before the middle of the sixteenth century, the motive



Belper.

power of water has, in comparatively recent times, been more extensively used in this country than in any part of the world; a circumstance which "has in no small degree contributed," observes Mr. Millington, "to that pre-eminent excellence which our country is acknowledged to have obtained in her various manufacturing processes. The application of water to the driving of machinery is so simple, so cheap, and so constant, so equable in its action, that it amply merits the preference constantly shown to it wherever it can be obtained."

As, however, the exercise of this power is dependent on abundant supplies of water, its application cannot be otherwise than limited to particular localities; and the introduction and general adoption of the steam-engine as a motive power, has, in great measure, superseded the use of water-mills in our large manufactories, thus obviating the necessity of fixing them on the immediate banks of streams; and leading to their establishment in situations favourable for obtaining supplies of fuel at a moderate cost.

But although in the present day, water-power has, in some degree, fallen into disuse in large manufactories, the important part which it *has* performed in forwarding the commercial interests of this country cannot be too highly estimated; and perhaps no stream has more lent its aid to accomplish this end, than the "ever-varying and ever-pleasing river Derwent," on whose richly diversified and beautiful banks, one of the first water-mills employed in this country for spinning cotton was erected in the year 1771, by Sir Richard Arkwright; and from the circumstance of motion being imparted to the apparatus by means of water, the machine was called the *water-frame*, and the thread received the name of *water-twist*. At Belper, again, the lovely Derwent also performs a similar office; Messrs. Strutt having four cotton-mills situated on the luxuriantly wooded banks of this river in that locality; forming, perhaps, the most extensive series of machinery, dependent on water as a motive power, either in this kingdom, or in any other country on the face of the globe.

CHAPTER X.

MOTION OF WATER IN RIVERS AND CANALS.

HAVING briefly considered the principal engines employed for raising water, and also those which are impelled by its gravity and by its force, let us now devote a few pages to the branch of hydraulics which comprises the motion of water in canals and rivers; an inquiry which cannot fail to be replete with interest in a country where inland navigation has been so extensively applied, and has led to such important results. This island may not, it is true, contain any vast rivers to compete in magnitude with those which water some other portions of the globe, yet the generally level nature of the surface, and the insular and moderate character of the climate, render those which it does possess more than usually available for inland navigation; and the active and enterprising disposition of the British people, has caused almost every possible advantage to be taken of the streams which intersect the island; whilst to these, no less than 2770 miles of navigable canals have been added.

The motion of water in canals and rivers is founded on the hydrostatic principle of equal pressure, arising from the fluidity of water, (which, as we are well aware, causes it to maintain a perfectly level surface in any channel in which it is contained,) and on the tendency of water to move in accordance with the laws of gravitation. Motion will not take place in an artificial channel, unless there be some inclination or descent in its surface; for, in fact, the latter circumstance, by giving the water free scope to descend by its own gravity, is the direct cause of all motion.

By the laws of gravitation, however, if no obstacle should occur, an *acceleration*, or increase of velocity in the flowing of the water, would take place as the distance from the head or source of the river or canal increased, and the motion of the fluid would never be uniform. But, as we have already seen

in speaking of pipes, water encounters resistance from its friction against the sides of any channel through which it passes; a remark which is equally applicable to our present instance. And it is a singular and highly interesting fact, that an admirable adjustment prevails, so that one law of Nature counteracts, and thus counterbalances another; it being found to be a general principle, that when water moves onwards in any channel or conduit, *the resistance which it encounters is equal to the force of acceleration;* or, in other terms, the friction is so greatly augmented by the increased velocity with which the water moves, that it retards the progress of the liquid, the one being proportionate to the other.

The perpetually varying character of the channels of rivers, each differing according to the nature of the soil through which it passes, and the slope or inclination of its bed, causes the amount of resistance from friction to vary in almost every individual case; and we find rivers subject to new conditions, dependent on every inequality of soil and country; but, whether we trace them to their sources among the rocky steeps of mountainous districts, or follow them across the alluvial soil of the valley, or the sandy plains, or from thence to their embouchure in the sea, we shall find that, like all other departments of nature, they are governed by well-defined laws. These laws are, however, too complicated for our present consideration, and it will suffice for us to direct our attention to a few of the more striking phenomena presented by running streams.

The motion of a river, or a canal, depends partly on its inclination or slope, and partly on the volume or quantity of water; and uniformity of motion can only be maintained when the channel has the same degree of inclination, and same depth, throughout its whole course. This, it will be evident, can never be the case in a natural stream, which we frequently find at first a rapid and impetuous torrent, "foaming down the shelving rocks," then rushing along a highly inclined bed; but latterly, perhaps, maintaining a calm and majestic course, according to the nature of the surface of the country which it

traverses. In artificial canals, however, uniformity of motion may be obtained, and, as we shall presently see, the regulation of the depth and inclination of canals, according to the purposes for which they are designed, becomes an object of great importance.

It has been found that the velocity necessary to maintain the salubrity of water, is about fourteen inches per second. A channel designed to form a water-course, must therefore be constructed with such a slope or inclination, as will allow the water to flow with that degree of velocity. This is considered to be about one in 12,000, or from three to four inches per mile; though, as the rapidity with which water flows is increased by the depth of the water, the slope ought to be regulated accordingly. The slope of the New River is three inches per mile, and the great "cuts" or drains in Norfolk and Lincolnshire, have an inclination of five inches to a mile.

It has been proved by experiment that the velocity in a stream is always greatest at the surface, and less at the bottom than in any other part. The water also moves with greater velocity in the middle of the stream than at the sides. This retardation or impeding of the progress of the lowest and lateral currents is produced by the friction against the sides and bottom of the channel; and when the velocity of a stream is very great, and the bed is not formed of very solid rocks, the soil of which it is composed frequently gives way, and the stream excavates for itself a deeper channel. A velocity of three inches per second at the bottom of a running stream has been ascertained to be of sufficient force to remove fine clay;—six inches per second, fine sand;—twelve inches per second, fine gravel;—and three feet per second, pebbles of the size of an egg. If, therefore, the water were to run with equal velocity in all its parts, it will be evident that the bed and sides of most rivers would not withstand the violence of its action, but would be continually giving way. But, owing to the retardation thus caused by friction, the force is greatly abated in those parts where it is important that the velocity should be lessened, whilst the central current flows with a degree of rapidity adapted

to preserve the salubrity of the water, and the consequent healthiness of the adjacent districts. This obstruction caused by the friction of the banks, is very evident, even to the most casual observer, and we shall find that an experienced boatman will regulate his station in a river according to circumstances. If the course of the stream be moderate, as that of the Thames near Twickenham, he will, when steering with the current, take the centre of the stream; but if contrary to the current, he will take his station nearer the banks. If, on the other hand, the course of a river be rapid, as in the river Esequibo, so as to render navigation in a small boat or canoe attended with risk, the boatman will keep as close to the banks as prudence will permit, even when steering with the current.

When we consider the great mechanical force of running water, transporting clay, sand, gravel, and even pebbles of considerable size, whilst moving at what might appear not any extreme velocity, we might at first feel surprised that rivers do not tear up and destroy their own channels, and thus, instead of continuing to exist in the form of navigable streams,—passing through, and enriching the fertile champaign districts of the globe,—burst their banks, and spread themselves over the surface, flooding the whole country, and presenting throughout their course, little besides torrents in the hilly districts, and vast sheets of water in the plains and valleys. And there can be no doubt that instances sometimes occur, where devastating effects are produced by running water; and that some considerable rivers have in this manner deserted their former beds, and excavated for themselves new channels; thus causing great physical changes in the face of the country through which their course lies. Such cases are, however, rare, and in general we shall find, that the changes in rivers, arising from the force of the running water, are comparatively of small amount. In this preservation of the beautiful rivers of the globe, we may discern the wise adaptation of the laws regulating the physical, or natural condition of the earth's surface, to its maintenance in a state fitted for its present inhabitants. The strata through which rivers

pass in the earlier and more rapid part of their course, are for the most part hard and rocky; and on such a channel, the force of the water produces little effect: some fragments, it is true, are occasionally rent from the harder rocks, and borne downwards by the stream; and it is well that they should be thus removed; for, were they permitted to accumulate in the bed of the stream, usually narrow in such parts, they would block up the channel. But when, in its more advanced progress, the stream descends into the plain, where the materials forming its channel are generally less consistent, the more level surface over which it passes, causes it to be less impetuous in its character, and its transporting power being diminished, the banks which restrain it within its limits are preserved.

Great changes, however, as we have already remarked, do in some instances occur in the channels of rivers; striking examples of which are presented by some of the Italian streams, and not only of such changes, but also of the triumph of science over these natural disadvantages. The peculiar physical character of the surface of Italy, intersected as it is in all directions by mountains, and by numerous torrents and rivers, which carry off the superfluous waters to the Mediterranean Sea on the one side, and the Adriatic on the other, render it especially subject to changes of this description. The lofty character of the mountains, as compared with the small extent of surface from thence to the sea on either side, causes the streams to descend with extreme rapidity into the valleys or plains, which are frequently ravaged and devastated, to an amount quite unknown in more level and more extended districts; and the changes which have been gradually effected in the great plain of Northern Italy within the historical era, are very considerable. Extensive lakes and marshes have been filled up by the soil brought down by the streams from the upper districts, particularly near Placentia and Parma; whilst others have been drained by the deepening of the beds of rivers. Deserted river-courses are of not unfrequent occurrence, these extinct rivers being sometimes designated as *morto*, or "dead," and as *vecchio*, or "old." Thus, the ancient, but now deserted bed of the Serio, which formerly fell into the Adda, in Lombardy,

is distinguished by the name of the Serio Morto; and the river Po, which has often deviated from its course, has had both these names applied to different extinct branches. The changes which have taken place in the latter river, are so illustrative of our subject, that it will be desirable to take a brief review of the most remarkable.

About the end of the fourteenth, or beginning of the fifteenth century, the river Po changed its course, deserting part of the territory of Cremona, and invading that of Parma; and its old channel through the former province may still be traced, bearing the name of Po Morto. The town of Bressello formerly was situated on the left bank of this river, but, owing to the change which took place at that period, now stands on the right bank. There is also another old channel of the river Po, in the territory of Parma, called Po Vecchio, which was abandoned by that river in the twelfth century, at which period the floods thus occasioned, caused the destruction of a great number of towns and villages. In the fifteenth century, the main branch of the fickle river again resumed its deserted channel, which, however, it once more abandoned at the end of the same century; and in the seventeenth century, tired of its new channel, it deserted the latter, but, in lieu of returning to its old course, shifted its place, forming for itself another new channel in the same district, about a mile distant from the preceding new one.

The evils arising from these changes in the river's course, were, as may well be imagined, very considerable; for, not only was the loss of life and the destruction of property of great amount, but the shifting channels of this and other rivers gave rise (and, indeed, still gives rise) to constant litigation and strife between the various states of Italy, of which, in many instances, the rivers constitute the boundaries, and which thus have been occasionally subject to an increase or loss of territory, as the river has changed its course. The attention of ingenious men was accordingly directed to the means of remedying these evils; "and hence," observes Mr. Rennie, "may be dated the origin of that science, which has since made such progress in Italy,

namely, the application of hydraulics to rivers, which may be said to have arisen in that country."

The arts of irrigation and drainage had, however, as we have already seen, long antecedent to this period, been known and carried into practice; but after the downfal of the Roman empire, all the scientific knowledge which had previously existed, appears to have become extinct, or at least to have remained wholly dormant, until the eleventh or twelfth centuries, when, in order to check the aberrations of their rivers, the Italians applied themselves to the task of raising embankments in several of these streams, among which were the rivers Po, Reno, Arno, Brenta, &c. These artificial mounds are thus referred to by Dante in *L'Inferno*:—

> As the Flemings rear
> Their mound, 'twixt Ghent and Bruges, to chain back
> The ocean, fearing his tumultuous tide,
> That drives towards them; or the Paduans theirs
> Along the Brenta, to defend their towns
> And castles, ere the genial warmth be felt
> On Chiarentana's top.

The rivers of Italy which excited the greatest degree of interest on account of the changes to which they were subject, were, however, the Po and the Reno; one branch of the former river having entirely absorbed the river Primaro; whilst another branch, by its vast depositions of alluvial matter, had blocked up the Reno, to so great a degree, as to cause the latter to burst its banks, and thus inundate the most fertile provinces of the Bolognese territory. The evil at the same period was greatly increased by the addition of five other torrents to the mass of waters.

Such an event was well calculated to increase the interest on the subject, and from this era, may be dated the rise of this branch of science in Italy. To guard as far as possible against the recurrence of so fearful a calamity, a general system of embankment was adopted, and the rivers Po and Adige, as well as the greater number of their tributary streams, have been and are now confined between high artificial banks. By being thus enclosed within fixed limits, the depths and conse-

quent velocity of the streams has been, however, augmented; the result of which is, that their transporting power is also proportionately increased, and these waters thus carry down a much larger portion of sand, mud, and other foreign matter, than formerly; and hence the deltas at the mouths of the rivers Po and Adige have increased more rapidly, since the practice of embankment has become general. Before these embankments were made, the rivers at the season of the melting of the snow on "Chiarentana's top," and the other mountains from whence they take their source, used to spread themselves over the plains, inundating the lowlands and valleys, and depositing in those localities an annual layer of sand and mud. This foreign matter now subsides in the bottom of the artificially enclosed river channels, and thus proves a serious inconvenience; for these channels are by this means so much filled up, that it is found necessary every year to clear the accumulated deposits from the bed of the river, and also to augment the height of their banks. The consequence of the latter operation is, that the mounds, or embankments, which form the present bed of these streams, have been raised considerably above the level of the plain; so that these rivers now traverse the country on the top of high mounds, like the waters of an aqueduct; and at Ferrara the surface of the river Po has become more elevated than the roofs of the houses. The maintenance of barriers of such magnitude and importance in a state of security, forms a subject of increasing anxiety as well as expense, to the inhabitants of the adjacent districts, it having sometimes been found requisite to give the additional height of nearly one foot to the banks of the rivers Adige and Po in a single season.

We have mentioned, as a subject which excited great interest in Italy, the absorption of the river Primaro by the river Po. This is a phenomenon well deserving our attention. It is a fact, and at first sight, appears a singular one, that a small river, or even a river of some size, may unite its waters with those of a larger river, without perceptibly either enlarging the channel, or sensibly raising the surface of the latter. This apparent para-

don, is, however, capable of easy explanation. The increase of volume, causes an increase of velocity in the enlarged river, proportionate to the augmentations received, and consequently, the waters are carried off and discharged, at a more rapid rate than they would be in the separate streams. And though, in consequence of this greater velocity, the power of abrasion, or wearing away of the beds, is increased, and thus the channels usually become deepened, the retardation by friction is less than it would be if the same quantity of water had continued to run in two separate channels. It is on this principle that the Primaro is absorbed by the river Po; the Inn by the river Danube, and the Mayne by the Rhine.

An acquaintance with this principle is of great importance in a practical point of view, for it clearly shows the inutility of forming side cuts in rivers, with the design of diverting the waters and carrying them off with greater rapidity in seasons of flood. The same remark will apply to drains; for if the channel be of sufficient size to bear the force and pressure of the larger volume of water, it is evident that there will be less friction in one large conduit than in two smaller ones, and that thus, the water will flow with greater rapidity with every fresh addition, but diminish in rapidity if side cuts be made, by which a decrease in volume would take place. The importance of drains or sewers of large dimensions, for carrying off waste waters, in preference to a number of smaller ones, is therefore very apparent: and, although, perhaps, the principle was unknown, it was carried into practice in very remote times. Thus, we read in Josephus, of the vast sewers beneath the city of Jerusalem, which were of such large dimensions, that after the burning of the city by the Romans, great numbers of the Jews took shelter in these subterranean retreats. The city of Rome was also provided with vast subterranean drains of the same kind, some of which still exist at the present day.

All beneath the vales and hills around,
Extend the caverned sewers; massy, firm:

Hark, how the mighty billows lash their vaults,
And thunder! how they heave their rocks in vain!
Though now incessant time has rolled around
A thousand winters o'er the changeful world,
And yet a thousand since, th' indignant floods
Roar loud in their firm bounds, and dash and swell
In vain, conveyed to Tyber's lowest wave.

But, on the other hand, if rivers divide themselves into two or more branches before they enter the sea, (as, for example, the Great Rhine, which, near Emmerick, separates into two branches of nearly equal size, called the Waal and the Rhine,) the area occupied by the streams of water, will be extended, and the depth and velocity diminished. Such instances are, however, comparatively rare (for we do not now speak of the divisions caused by deltas); the junction of two or more streams before they reach the sea, being by far the most usual condition in the natural course of rivers. The effects produced by the divisions and sub-divisions of the Rhine form a highly illustrative example of the above remarks. This river, as we have just seen, divides itself into two branches, the Waal and the Rhine. The latter, subsequently, among other affluents, or tributary streams, receives the rivers Mayne and Moselle, without experiencing any sensible increase of its channel; but, besides other minor sub-divisions, it once more, near Arnheim, divides itself into two considerable streams, distinguished as the Rhine and the Ysel. These divisions of the Rhine are, however, artificial, the river having been divided by the Romans into numerous channels for the purpose of affording the facility of inland navigation across different tracts of country. Other sub-divisions were made in later ages; and although this great multiplicity of channels, thus intersecting the territory of Holland, has been productive of advantage to that country in a commercial point of view, numerous fatal consequences have ensued, wholly attributable to this sub-division of the Rhine; the waters of that noble river, from being separated into so many branches, having thus lost the strength and rapidity required to push forward the alluvial matter brought down by the stream from the higher districts; for, owing to

the flat nature of the country in the latter part of the river's course, a very considerable volume of water was required to maintain its velocity across so level a surface. Accordingly, when these divisions had been made, the alluvial matter, instead of being carried forward to the sea, was deposited in the beds or channels of the separate streams, thus occasioning a continual rising of these beds; which being thus, like the Italian rivers before alluded to, raised above the level of the flat surrounding districts, it became imperatively necessary that they should be guarded from overflowing, by dykes, or embankments: thus, not only leading to vast expense, but also, not unfrequently, by the occasional bursting of these barriers, to great loss of life, and destruction of property. And yet farther to increase the evil, the beds of these streams being now more elevated than the surface of the intervening plains, the superfluous waters could no longer be drained into and carried off by their former natural outlet, and consequently have accumulated in the lowlands, forming extensive marshes and lakes, thus causing an actual loss of profitable land.

This train of evils originated, as has already been stated, in changes affected by the hand of man; and such sub-divisions of rivers near their embouchure are very rarely met with in the natural world. An instance, however, does occur in the Mississippi, from which river, a branch, called the Atchafalaya, or "lost water," diverges at the distance of about 250 miles from its embouchure. When the Missisippi is full, an immense body of water is carried down this branch; but when the former river is low, the water sometimes flows back into it from the Atchafalaya.

Such sub-divisions are, however, as we have already remarked, uncommon; and, indeed, in the more usual arrangement exhibited in the progressive increase of a river by its junction with successive tributary streams, we may trace a beautiful and most beneficial adjustment: for, the collective waters, instead of spreading out over a larger horizontal surface as they approach the sea, are thus made to occupy less space; and not only are the richest districts by this means preserved from

continual inundation, but the additional volume of water, as we have already seen, causes the velocity of a river to be maintained in the more level part of its course, where, owing to the smaller degree of inclination in the surface, the rapidity of the stream would otherwise be checked. This increase of force near the embouchure or mouth of a river, is also of importance in preventing the accumulation of shoals and sandbanks, which otherwise would increase with great rapidity, and choke up the entrance; but, on the other hand, it rather favours the formation of deltas, or rich alluvial deposits, near the mouth of the river, owing to the greater quantity of foreign matter borne down by the more powerful current. And, at the same time, the greater volume or depth of water contained in a river after its junction with other streams, renders that portion of a river which crosses the most valuable districts of our continents, more especially adapted for purposes of navigation.

The river Mississippi displays, on the grandest scale, the action of running water on the surface of a vast continent. This magnificent stream rises nearly in the 49th parallel of north latitude, and flows to the Gulf of Mexico—a course, including its meanders, of little less than 5,000 miles. No river affords a more striking illustration of the law before mentioned, that an augmentation of volume does not usually produce a proportional increase of surface; nay, is sometimes attended with the narrowing of the channel. The Mississippi is half a mile in width at its junction with the Missouri, the latter river also possessing an equal width; and the united streams, from their confluence to the mouth of the Ohio, have only an average width of three-quarters of a mile; whilst the junction with the Ohio, so far from producing an increase, causes rather a decrease of surface. As the Mississippi proceeds onwards in its majestic course, it receives the river St. Francis, the White river, the Arkansas and Red rivers, all of which are absorbed by the main stream, without any apparent increase of surface; and when at length, after having received these, and all its other numerous affluents, some of which are

mighty rivers, it approaches the sea at New Orleans, it is scarcely half a mile in width; the surface of this vast accumulation of waters in this part being, as will be perceived, rather less than that possessed by the river before its confluence with the Missouri. But though thus remarkable for maintaining this moderate width, the Mississippi is at least equally remarkable for its great depth. "It is the depth," observes Captain Basil Hall, "which gives this mighty stream its sublimity." The average depth of the river, from the confluence of the Missouri, is said to be about 100 feet; and though, owing to the occurrence of shoals, the depth is in some places reduced to 50 feet, the greatest depth at New Orleans, has been estimated at no less than 168 feet.

CHAPTER XI.

NAVIGABLE CANALS.

In a commercial country like Great Britain, the importance of inland navigation by means of rivers, or, where these do not exist, by the formation of artificial water-courses,—

> To teach
> The stream a naval course, to till the wild,
> Or drain the fen, or stretch the long canal:

has caused our island to be intersected in nearly every direction by navigable channels, reaching almost to its remotest extremities. At an early period of English history, and long before the construction in this country of navigable canals, great attention appears to have been paid to the preservation of a free and convenient communication in our navigable rivers; an express clause to that effect being inserted in the Magna Charta: and at subsequent periods, acts of parliament were from time to time passed for the conservancy of our rivers, by causing them to be deepened and straightened, and also embankments to be made, where necessary; and likewise, by means of weirs and sluices, penning up the surface of the water, or lowering it, as

might be required, for the purpose of removing or overcoming the obstructions to navigation. Various drawbacks, however, attended these attempted improvements, which sometimes, indeed, owing to want of proper management and other causes, increased instead of remedying the evil they were designed to remove. The circuitous navigation also, when following the windings of a river, and the trackage against the current, when ascending a stream, or proceeding against the tide, at all times rendered the progress along a river laborious and dilatory. These difficulties attending inland navigation, at length suggested the idea of substituting artificial canals for the natural beds of rivers, or of forming short cuts, by which the course of a stream might be materially shortened, or in some cases, water-falls and other obstacles to navigation avoided.

England, however, was behind her neighbours in the introduction of works of this description. Encompassed by the ocean, and possessing good harbours, as well as some navigable rivers, her principal commercial towns,—London, Liverpool, Bristol, Hull,—rose in situations which gave them the command of water-carriage; and the principal manufacturing towns also, with the exception of a few which acquired importance from other local advantages, were situated on rivers, both for the convenience of water-carriage, and also with the view of profiting by the water-power afforded by the stream, in turning mills for working the various kinds of machinery.

The introduction of the steam-engine, however, as we have already remarked, formed a new era in the manufactures and commerce of the country. The manufacturer was no longer dependent on a running stream for the moving power of his machinery, and manufactures could be carried on with advantage in districts remote from any river. With the increasing manufactures, however, the importance of inland water-carriage became more and more apparent; and this consideration led to the formation of the numerous navigable canals which intersect the island, the greater number of which were constructed towards the close of the last, or the commencement of the present century. Before giving our attention to the British

[illegible] us, however, take a slight glance at the progress [illegible] works of this description at a period antecedent to [illegible] introduction into Great Britain.

Navigable canals are of very ancient date, Egypt having been celebrated for its canals from the earliest periods of history. The most celebrated of these was one that was carried across the isthmus of Suez, the design of which was to form a communication between the Nile and the Red Sea. This great undertaking was commenced by Pharaoh Necho, about 600 years before the Christian era; but after his death, appears to have been discontinued until Egypt fell under the Persian dominion, when Darius Hystaspes made some progress in the work; but it appears doubtful whether it was ever completed, according to the original design of carrying it entirely across the isthmus. It was on a magnificent scale, being described by Herodotus as of sufficient width to admit of four vessels passing abreast. According to some accounts, it was completed by Ptolemy Philadelphus.

The first canal known to have been constructed in Europe, was one formed by Xerxes during his invasion of Greece. This canal extended across the low isthmus which unites the peninsula of Athos, or Monte Santo, with the mainland. It may still be most distinctly traced nearly the whole way across the isthmus, the distance of which, however, does not exceed a mile and a half. The width of the canal appears to have been about eighteen or twenty feet, and in many parts, it is still deep and swampy at the bottom, and filled with rushes and other aquatic plants. Little, however, did the construction of this navigable passage avail the Persian monarch: his fleet was destroyed off Salamis, and he was forced to retreat with dishonour to his own country; but it is not a little remarkable, that this canal of Xerxes is at the present day of considerable service to other navies. The rain and small springs which drain down into it from the adjacent heights, collect in this spot, and, except in very dry weather, it thus affords, on the western side, a good watering-place for shipping.

The Romans, among their other stupendous works designed

for water-courses,—their splendid aqueducts, and spacious sewers,—also turned their attention to the construction of navigable canals. Among the most remarkable of these was that of the Pontine Marshes, which, though primarily designed to act as a drain in drawing off the waters from that swampy district, was also applied to the purposes of navigation. The falling to decay, and disuse of this drainage, renders the district across which it was carried, at some seasons of the year, wholly unfit for the abode of man.

The Roman canals to which, however, we design more especially to direct our attention, on account of their more immediate interest to ourselves, are those which were constructed by the Romans in Britain, and of which evident traces still remain in many parts of the island. Such are the Caer and Foss Dykes in Lincolnshire. The Foss Dyke connects the Witham at Lincoln with the Trent above Gainsborough, by a level cut of eleven miles in length. The Caer, or Carr Dyke, skirts the uplands and fens, from the river Nene at Peterborough, to the river Witham near Lincoln, having formed a canal forty miles in length. This work, like that of the Pontine Marshes, served the double purpose of a drain for the superfluous waters of the district it traversed, and of a navigable canal. The late Mr. Rennie, speaking of this Roman work, observes, "I have traced its course, for the greatest part of the way, and a more judicious and well-laid out work I have never seen." "If the Carr Dyke," continues Mr. Rennie, "were in good condition, and with a proper outlet, it would greatly relieve the whole level." It will, however, be observed, that these canals of the Romans were connected with the drainage of the adjacent districts; and, in fact, before the invention of the canal lock, very little beyond this could be done in the way of artificial navigable water-courses.

The system of inland navigation, by means of canals, has been long and extensively practised by the Chinese, some of their canals being supposed to have been in operation for nearly 2000 years. As their canals do not appear to have been mere "catch-water-drains," like those of the Romans,

they are deserving of some attention. The object in the Chinese canals seems to have been to carry inland navigation into the very interior of the country, and accordingly they were formed nearly at right angles with the principal rivers, most of which run from west to east; but, in accomplishing this design, the canals, in many instances, were carried across high and hilly districts, in consequence of which the different parts of the canal would necessarily be on different levels. It therefore became requisite, that some mode should be adopted of conveying the barge or vessel, from the upper to the lower division of the canal, or in the contrary direction, according to circumstances. This is generally effected in China by means of an inclined plane and rollers, along which the vessels are drawn by men. In some of these inclined planes the ascent and descent is fifteen feet. The banks of the Chinese canals are frequently lined with masonry; and they are usually provided with sluices to let off the water, for the purpose of irrigating the country, and supplying the towns on their borders with water.

In modern Europe, canal-making appears to have been first revived in Northern Italy and in the Netherlands. In the latter territory, the formation of canals began in the twelfth century; and it was in great measure due to this circumstance that Flanders became the entrepôt of Europe, and rose to its commercial eminence. The Italians, in the eleventh and twelfth centuries, applied themselves to the task of rendering navigable several of their rivers, such as the Brenta, Arno, &c.; and about the same period constructed several canals for irrigation and drainage. But it was only after the invention of the *lock*, for transporting vessels from one level of a river, or canal, to another, that a new career was opened to hydraulic architecture.

A *lock* consists of a chamber, formed of masonry, occupying the whole bed of the channel where the difference of level is to be overcome. This chamber is so contrived, that the level of the water which it contains, may, as required, be made to coincide with that in the upper or lower canal. This is

effected by two pair of gates, one pair being placed at each end of the chamber. When the gates at the lower end of the lock are opened, and those at the upper end closed, the water within the chamber will, of course, stand at the same level as that in the lower portion of the canal; but when the gates at the lower end are closed, and those at the upper end opened, the water which enters the chamber from above, is penned or *locked* up, so as to maintain in the lock, the same level as that in the more elevated portion of the canal. And thus, if a barge or vessel, be required to be transported from a lower to a higher level, it is first floated into the lock, from its station in the lower part of the canal; the lower gates being then closed, the water is gradually admitted into the lock from the upper part of the canal, until the water in the lock, is level with that in the latter. The vessel of course rises with the rise of the water, and the upper gates being then opened, it may be passed onward into the upper part of the canal. By reversing this mode of proceeding, and letting the water gradually escape, boats may be readily conveyed from the upper to the lower level. "By this beautiful contrivance," observes Mr. George Rennie, "all the difficulties attending navigation were overcome, rivers were rendered navigable, or avoided when too rapid or too dangerous, whilst the irregularities of the surface of a country were compensated."

The precise period of the invention of this important piece of hydraulic machinery, and, consequently, the name of the individual to whom the invention is due, appears to be involved in obscurity; but there seems to be little doubt that it was first practically applied in Italy. According to Mr. George Rennie, the Naviglio Grande, which extends from Milan to the River Picino, was undoubtedly the first canal constructed with a lock. This is supposed to have been formed in the thirteenth century; but it was not until the close of the fifteenth century, that canal-locks were made use of to their full extent. At that period, the celebrated Leonardo da Vinci, who to his eminence as a painter, and cultivation of the fine arts generally, added great skill in mechanics, as also in many other

branches of science, accomplished the feat of uniting two canals of different levels, by means of a series of locks. This work was performed under the auspices of Louis Sforza, duke of Milan, who had formed the project of supplying the city of Milan with water from a distant source, though with the further design of applying this canal for the purposes of navigation. To effect this twofold object, and to carry a navigable channel across hills and valleys, appeared at that period next to impossible; but the task was happily accomplished by Leonardo da Vinci; a navigable channel, called the canal of *Mortesana*, being formed, above two hundred miles in length, which, passing through the Valteline and the valley of Chiavenna, conveyed the river Adda to the very walls of Milan.

This application of the canal-lock having been once successfully made, it will be readily supposed that its use did not stop here. And it appears, in fact, that a canal, constructed with a series of locks, and in part connected with that above-described, was formed about twenty years later by Francis I. On the accession of that spirited prince to the throne of France, he devised various plans for the improvement of inland navigation; and among others, was that of opening a communication from the lake of Como to the city of Milan, by means of the before-mentioned canal of Mortesana, and the river Adda. The hilly nature of the country through which the latter flowed, and the consequent impetuous nature of the streams, rendered this a task of no small difficulty; but the obstructions to navigation were overcome by a short cut, or canal, parallel with the rapid portion of the river Adda, and provided with ten locks. This work, called the canal of *Paderno*, was completed in the year 1520. The contests in which Francis was subsequently engaged with the Emperor Charles V., however, put a stop to these projects of the French monarch, and it does not appear that any other of his designs for the improvement of inland navigation, were carried into execution.

Canal navigation, on any scale of importance, does not appear to have been introduced into France proper, until the beginning of the seventeenth century. At that period, the canal of

Briare was projected; but this canal, though commenced in 1605, during the reign of Henry IV., was not completed until that of his successor, Louis XIII., in 1642. This canal, called also the canal of the *Loire and Seine*, because its object was to connect those two rivers, is about thirty-four miles in length, and contains at least forty locks. It is important for supplying Paris with provisions from the interior provinces. The *canal du Midi*, or canal of *Languedoc*, is another very important work. This canal, which was effected during the reign of Louis XIV., was designed to form a communication between the Mediterranean Sea and the Atlantic Ocean. The canal is one hundred and forty-eight miles in length, extending from Cette, on the coast of the Mediterranean, to the Garonne, the navigation being carried on by means of that river to the Atlantic Ocean. This vast work, which was completed in 1680, contains a hundred and fourteen locks, is crossed by ninety-two road-ways, and has fifty-five aqueduct (or rather viaduct) bridges, carrying the line over the various valleys it traverses in its course.

The construction of canals commenced in Russia under Peter the Great. The most remarkable Russian canal is that of *Vishna-Volosholk*, the object of which was, by connecting the rivers and lakes situated in that line, to open a water communication between Astracan and Petersburgh, a distance of 1434 miles, and thus, between the Caspian and the Baltic. Various other canals have been formed in Russia; and so extensive are the means of inland navigation in that empire, partly by canals and partly by rivers, that goods may be transported, by water-carriage, from the very frontiers of China to Petersburg, a distance of 4472 miles.

In more recent times, canals have been constructed in Germany, Denmark, and Sweden, though not any sufficiently remarkable to detain us at present, except the canal of *Keel* in Denmark, and that of *Trölhatten* in Sweden. The canal of Keel is chiefly remarkable from its opening a communication between the Baltic Sea and the German Ocean. The canal of Trölhatten, however, presents more interesting features, being remarkable for the bold and rocky character of the country

through which it passes, near the rapids of the river Gotha, which consist of successive cascades, one of which is sixty feet in height, the whole amount in the fall of the river being 114 feet. These rapids totally interrupted the navigation of the river Gotha for the distance of about two miles; and the project of constructing works by which to pass this portion of the river was long contemplated, but the rocky nature of the country, appeared to present an almost insurmountable obstacle to its accomplishment. This gigantic work, was, however, performed in the year 1800, by means of a circuitous canal, and these rapids are now avoided, and the line of navigation continued, by a canal containing nine locks, mostly excavated out of the solid rock.

The improvement of inland navigation by artificial means, does not appear, as we have already remarked, to have made much progress at an early period in Great Britain; and it was not until the reign of the Stuarts, that this department of hydraulics was practised with any regard to scientific principles. At that time, however, practical engineering, which has since flourished in this country with such unparalleled success, was introduced in a scientific form, the first efforts having been directed towards drainage.

The immense district, including the fens of Lincolnshire, and the tract called the Bedford Level, consisted, in great measure, of a morass, in many parts covered with stagnant water, which, in some places, stood from ten to twenty feet deep; whilst in the few spots where the earth was not covered with water, the soil was spongy and boggy. The inhabitants of the fenny districts, and of the towns in their neighbourhood, could only hold communication by means of boats, and this with some difficulty at all seasons, on account of the sedge and slime with which the ground was covered; but in winter, when the surface of these swamps and morasses was frozen over, and the ice not sufficiently hard to admit of traffic, the inhabitants were completely isolated, and at times in danger of perishing for want of food. The superficial contents of the fenny tracts

in this immense district, have been estimated at 1615 square miles, or above a million acres.

The practicability of draining this extensive morass, appears to have been long entertained, and so far back as the year 1436, in the reign of Henry VI., some attempt of the kind was made; embankments having been raised, and ditches or drains cut at a very great expense; but, as these were not constructed on scientific principles, the works gave way with the next winter's floods, and the attempt was abandoned in despair. In the year 1478, another attempt was made with greater success by Bishop Moreton, to drain some portion of these fens. This cut, called *Moreton's Leame*, had a width of forty feet, and was navigable. It extended from Peterborough to Guyherne*.

Another attempt to drain these fens was made in the reign of Elizabeth; and yet another in that of her successor; but nothing effectual was accomplished until the year 1634, in the reign of Charles I., at which time the project was formed of draining these fens on a grand scale, by Francis, earl of Bedford, and it was in compliment to that nobleman, that the tract thus reclaimed, has been named the *Bedford Level:*

> Bedford Level erst,
> A dreary pathless waste;
> * * * * * * *
> 'Till one of that high-honoured patriot name,
> Russell! arose, who drained the marshy fen,
> Confined the waves, bade groves and gardens bloom,
> And through his new creation led the Ouse,
> And gentle Camus, silver winding streams.
> God-like beneficence! from chaos drear,
> To raise the garden and the shady grove.

The rivers that drain this immense district, though numerous, had naturally too small a volume of water in proportion to their inclination, to carry down the waters with sufficient force to keep the channel clear. The great estuary, or bay, through which the different rivers disembogue themselves into the German Ocean, is very shallow, and full of shifting

* This cut was subsequently improved by Charles I., and it now is considered as part of the river Nene.

sands. The rivers which, especially in times of flood, are loaded with silt, are met in this estuary by the tide, equally charged with silt and sand; and hence a sediment is deposited, and banks are formed, at the mouths of the rivers, at a greater or less distance, according to the force of the current; and the nearer the bank, the more will it prevent the free egress of the superfluous water drained from the fens.

We have before seen, that when a river has a small degree of inclination in its channel, this may be compensated by an increase of volume, because the current of a stream moves with much greater force when the body of water is larger. In order, therefore, effectually to drain the fens, and also to prevent the further increase of sand-banks at the mouths of the rivers, the remedy that would naturally suggest itself, would be, if possible, to augment either the inclination of the channel, or the volume of water, in the rivers flowing across such a district. It is upon this principle, that the drainage of the Bedford Level has been effected. The drainage here passes off by the rivers Ouse, Nene, and their tributaries, which discharge their waters into the great estuary, usually designated as "the Wash," but called by the Romans, the Metaris Æstuarium. The river Ouse enters this estuary near Lynn, and in the year 1720 a plan was projected by Mr. Kinderley, of forming a direct cut across the marshes from a place called Eau Brink, to Lynn, a distance of about two miles and a half, instead of allowing the waters of that river to flow by their old circuitous channel, which was upwards of five miles in length. This plan was not, however, carried into execution until above a century later, having been only completed in 1825, under the superintendence of the late Mr. Rennie. By means of this cut, called the *Eau Brink Cut*, the slope is of course considerably increased, there being now the same fall in two miles and a half, as there was previously in twice that distance. The volume of water is also augmented, new cuts or drains having been made in various directions through the fens, with an inclination in their beds of from three to five inches in the mile, all of which are carried into the Eau Brink Cut. Be-

sides these drains intersecting the fens, a "catch-water drain" (*i.e.*, a drain to catch the waters from the upland districts, and prevent them from entering the marshes,) has been formed round the base of the hills skirting the fens, and the water thus collected, is conveyed into the Eau Brink Cut, by which means the volume of water in the latter is yet further augmented. By this magnificent drainage, the object of preventing the accumulation of silt and sand at the mouth of the river, has been effectually accomplished, nay, more, the previous accumulations have been carried off, the harbour of Lynn having been deepened above seven feet since this cut was made. And in the line of country between Eau Brink and Lynn, in a spot where before there was a depth of twelve feet of water, there is now a tract of 900 or 1000 acres under cultivation. This gain of land is, however, trifling, when compared with what has been effected by drainage in some other parts of these fens. One instance must, however, suffice us. In the districts drained by means of the cuts communicating with the river Witham, where formerly—

> The ox hath stretched his yoke in vain,
> The ploughman lost his sweat; and the green corn
> Hath rotted ere his youth attained a beard;

no less than 40,000 acres of valuable land have been wholly reclaimed; and the increased annual income in these fens, due to the process of drainage, has been estimated at 81,500*l*. Some of these lands have been raised and rendered fit for cultivation, by the process of *warping*, that is, allowing the waters to deposit the earthy matter borne down in times of floods; a practice frequently adopted in Italy, where it is called *colmata**.

But, although some of these cuts were, as we have seen, designed to perform the part of navigable channels, as well as of drains, the latter was, in fact the leading object in their construction; and the first navigable canal, formed exclusively for the purposes of navigation, was the *Sankey Brook Canal*, which

* From *colmare*, "to heap up."

was completed in 1760. This canal extends from the Sankey Brook, in the river Mersey, to the coal-pits at St. Helens, the object being to supply Liverpool with coals from the pits at St. Helens. The formation of this canal may be regarded as a new era in the annals of our internal improvement. "Great and important works had already been executed: rivers had been deepened and rendered navigable; the metropolis was already supplied with water by the New River; fens had been drained and brought into cultivation; but it was reserved for the more peaceful era which followed the accession of George III., and for the increased and increasing national means of this period, to achieve the vast system of interior navigation, which has contributed so greatly to the commercial interests of the country."

Before this period, however, locks had been introduced into some of our rivers. According to some accounts, the first lock known in this country was one erected on the Exeter navigation in the year 1675. Other accounts, however, assign the first introduction to Sir Richard Weston, who is said to have brought it from the Netherlands, at about the same period, and to have constructed locks on the little river Wey in Surrey; that stream having thus been rendered navigable.

We have just seen that the Sankey Brook Canal was the first opened for public use in England. Before this was finished, the Duke of Bridgewater commenced the well-known canal which bears his name. The object of this canal was to open a communication between Manchester, and the Duke's extensive coal-mines at Worsley. The obstacles were so great, both from nature and art, that the undertaking must altogether have failed, had not the plans of the projector been seconded and carried out, by the genius of the celebrated engineer, Brindley, who, from a common mill-wright, rose to the highest eminence in his profession. No locks were introduced in this canal, the whole channel of which was so constructed, that the water presented a level surface. To accomplish this, however, every resource of art had to be called forth: the canal being carried through vast excavations, partly in the interior of the mine

itself, and partly in subsequent portions of its course. Deep cuttings were effected in other parts; and artificial mounds in others; whilst it was carried over numerous public roads by means of aqueducts, besides the magnificent aqueduct bridge over the river Irwell at Barton, which was thirty-nine feet above the level of the water, and thus of sufficient elevation to allow vessels to pass under it at full sail*. By such means, this remarkable canal was carried on a level for the distance of fifty miles.

The Duke of Bridgewater expended on this grand undertaking, the whole of his fortune, amounting to 350,000*l.*, and its failure would have left him destitute; but the event proved otherwise, for coals being now conveyed with such facility from the duke's coal-mines to Manchester, he was enabled immediately to reduce the price of that important article to one-half of its previous cost, and as the demand in consequence increased in a manifold ratio, the trade became so great, that ere long it yielded twenty per cent. on his original outlay, thus rapidly producing an enormous income. It is not, however, the duke and his heirs alone who have profited by this noble work; this canal having no less tended to promote the public prosperity of the realm, than to enrich the projector's family; and the wealth which this nobleman was the means of creating, has been diffused amongst every class of his countrymen.

An impulse being thus given to the promotion of inland navigation, the duke's example was soon followed by other projectors; and, within forty-two years of the completion of the Bridgewater Canal, application had been made to parliament for no less than sixty-five acts, for cutting canals in Great

* When Brindley proposed carrying the canal over this river, by this aqueduct, at the elevation of thirty-nine feet above the water, he desired, for the satisfaction of his employer, to have another engineer consulted. It is related, that the individual called in to give his opinion, on being taken to the place where the proposed aqueduct was to be constructed, sarcastically remarked, that "he had often heard of castles in the air, but never shown before where any of them were to be erected." The duke, however, placed such confidence in Brindley, that he was not to be deterred from pursuing the plans of the latter; and the aqueduct bridge was completed with entire success,

Britain. It is related of Brindley, that on one occasion, when attending a Committee of the House of Commons relative to this subject, he expatiated with considerable warmth on the superiority of canals over rivers, the course of the latter being usually circuitous, and presenting various obstacles to navigation, so that in many cases it was found advantageous to construct canals parallel to rivers, instead of carrying the navigation along the latter. One of the members present asked him, "For what purpose, then, has Nature intended rivers?"—To which he readily replied, "To feed navigable canals."

The *Grand Trunk Canal*, which was begun in 1766, under the superintendence of Brindley, was an undertaking on a yet grander scale than the Bridgewater Canal. The length of this canal is ninety-three miles, and it crosses the ridge of hills which traverse the island from north to south, the object being to unite the navigation of the Mersey with that of the Trent and Humber; thus forming an inland water communication between the western and eastern counties, but especially between Liverpool and Hull. In crossing the ridge of hills before mentioned, this canal passes through a tunnel nearly a mile and three quarters in length, and in some parts 210 feet below the surface. Brindley gave the name of the Grand Trunk Navigation, to this canal, because he considered it probable that, from its great commercial importance, many other canals would be formed as branches from this trunk. Nor was he mistaken in this conclusion, for it not only gave animation to the trade of all the districts through which it passed, but also formed the centre from whence various canals and railways diverged. Thus, from its eastern extremity, lateral branches have extended to Derby, Nottingham, Grantham, and other considerable towns; whilst, from its western side, the *Ellesmere Canal* branches into Wales, and by this means the mineral and agricultural produce of that principality finds easy access to Liverpool. The latter canal is remarkable for two fine aqueduct or viaduct bridges; that of Chirk, in Denbighshire, and that of Pont-y-Cysylte, in the vale of Llangollen. The Chirk aqueduct consists of ten arches, supported by pyramidal piers of

stone, and extends about 600 feet in length, the height of the central arch above the water being about sixty-seven feet. The aqueduct of Pont-y-Cysylte, which crosses the Dee at the distance of about twenty miles from Chester, is on a grander scale. This aqueduct is supported on nineteen stone pillars, and extends for 988 feet, having an elevation of 125 feet above the river. It presents a singular and highly picturesque appearance, spanning as it does the beautiful valley below, and seeming to suspend high in the air, the vessels which pass along this portion of the canal, whilst the Dee, undisturbed by the traffic on the artificial water-course above it, still flows beneath, retaining all the repose and all the beauties of its natural scenery.

The *Leeds and Liverpool Canal*, by a more northerly route, also forms a line of water communication between Liverpool and Hull. This canal, which is 120 miles in length, connects the Mersey with the Aire, a tributary of the Yorkshire Ouse, which latter falls into the Humber. This line passes through the great cloth-manufacturing districts, and important branches extend from this canal into Lancaster and Kendal.

Canal navigation has also formed an object of attention in the less northerly districts of the island; and in the year 1805 the *Grand Junction Canal* was constructed, extending from the vicinity of London to Coventry, a distance of ninety miles. Near Daventry, the *Grand Union Canal* strikes off from the Grand Junction, and joins the Grand Trunk, thus forming an inland communication between the metropolis and Liverpool, as well as with all the great manufacturing towns of the western districts.

The *Thames and Severn Canal* unites these two principal rivers of the island, whilst, by means of the Berks and Wilts Canal, a communication is formed from the river Thames, near Abingdon, to the cities of Bath and Bristol. The canals to the south of the river Thames are comparatively few and unimportant; indeed, the absence of large manufacturing towns in these districts, and the greater proximity of this portion of the island to the sea, render them much less called for than in the more central counties.

In North Britain, owing to the general ruggedness of the surface, canal navigation meets with peculiar obstructions; and hence works of this description have never been numerous in Scotland. As early as the year 1768, however, a canal, distinguished by the name of the *Great Canal*, was undertaken by some citizens of Edinburgh and Glasgow. The object of this canal was very important, it being designed to unite the German and Atlantic oceans, by means of a channel, along which vessels of considerable size might pass from the Frith of Forth to the Clyde, and thus avoid the circuitous and frequently perilous voyage, round the northern shores of the island. Want of funds occasioned a long delay in the execution of this useful undertaking, but it was ultimately completed in the year 1790.

The *Caledonian Canal*, which is on a far more magnificent scale than the preceding, had a similar object in view, and, like that, crosses the entire breadth of the island. In our present instance, the chain of lochs, or lakes, which intersect Scotland in a diagonal direction, extending through the counties of Inverness and Argyle, suggested the idea that a water communication might be formed, by which large merchant-vessels, and even ships of war, might pass from the German Ocean into the Atlantic, without encountering the perils of the Pentland Frith and Cape Wrath; and accordingly this great work was commenced in 1808, under the superintendence of Mr. Telford. The nature of the ground, and the different levels of the successive lakes, presented vast difficulties in the accomplishment of this undertaking; but every resource of science was called forth, and the canal was completed in 1822. An inland navigation of 250 miles has thus been formed across the very central districts of Scotland, extending from the Murray Firth, on the eastern coast, to Cantyre, on the western side of the island. At Fort Augustus, the canal is cut through the glacis of the fortification, thus adding to the strength, as well as the appearance, of the fort; which, with the five locks formed of solid masonry rising behind, presents a remarkable combination of both civil and military engineering, united with highly

romantic scenery. The obstacles to be overcome in this undertaking may in some measure be conceived, when it is stated, that in the distance of eight miles, (that is, from Loch Lochy to Loch Eil,) the canal passes, by means of aqueduct-bridges, three large streams and twenty-three smaller ones, whilst in the last two miles, just before it enters Loch Eil, where this line of navigation opens into the Western Sea, there is a descent of 64 feet, which is passed by a series of eight connected locks, each 180 feet in length, by 40 in breadth; the whole forming a solid and continuous mass of masonry, 1500 feet long, and 60 wide. This system of locks is called by the sailors, Neptune's Staircase, and it may well be supposed that the appearance of large vessels descending the mighty flight of steps, formed by these stupendous locks, must present a magnificent and imposing spectacle. The formation of a great line of communication through any part of a country, usually, also leads to improvement in the districts across which it passes; and it appears that since the construction of the Caledonian Canal, upwards of a million of forest trees have been planted along its borders.

Canals, which have proved so beneficial to the commercial prosperity of Great Britain, have been conducted on a bold and extensive scale in Ireland. The two principal works of this kind in the latter country are the *Grand Dublin* and the *Royal Irish Canals*, both of which extend, by different routes, from Dublin to the river Shannon. The commencement of the Grand Dublin Canal was nearly coeval with that of the Sankey Brook Canal, though it was not completed until 1776. This canal passes through Kildare and King's County, and joins the Shannon near Clonfert, about sixty miles above Limerick. It is carried for twenty-four miles across a bog, and the absorbing nature of the soil rendered the construction of the canal very laborious, as well as expensive, in this part of its course. The Royal Irish Canal joins the Shannon at Tarmonbarry, about forty miles above the junction of that river with the Grand Dublin Canal. The Royal Irish Canal passes through the counties of Meath and Longford; its

greatest elevation above the sea being 307 feet, to which it ascends from Dublin by means of twenty-six locks, whilst the descent to the Shannon is effected by fifteen locks.

These canals have, however, failed of producing the benefits anticipated to Ireland from their construction, a circumstance which, though doubtless arising in part from other causes, is mainly attributable to the obstacles presented to navigation in the river Shannon. This river, instead of forming one continued stream, may be considered as consisting, from its source in Lough Allen to its termination in the sea, of a series of lakes and rivers; the consequence of which is that the soundings vary greatly, the water being in some parts very deep, whilst in others it is equally shallow. The bed of the Shannon is also much broken by islands and rocks, and in seasons of flood is subject to be overflowed to a great extent on both its banks, whilst great detriment has arisen to navigation from the land-floods. The importance of improving the navigation of this noble river, which is without a rival in the British Isles, had long been felt, and is even supposed to have originated with the celebrated Earl of Strafford, who was appointed lord-deputy of Ireland in 1631*. It does not, however, appear that anything was effected at that period. The subject was again revived in 1703, when an Act of Parliament was passed, and a sum of money granted for that especial purpose; but on this occasion, as well as at subsequent periods, when further grants were made for the same object, nothing effectual had been accomplished; but in the year 1841, active operations for effecting this important undertaking were commenced, and there is reason to hope that ere long the shoals and other obstacles to the free navigation of the river Shannon will be

* To this nobleman is also due the introduction of the linen manufacture into Ireland. At his own risk, he imported and sowed a quantity of superior flax-seed. The first crop having succeeded, the following year he laid out 1000*l.* on the undertaking, established a number of looms, and procured artisans from France and Flanders. Ere long the earl was enabled to send a ship to Spain, freighted with linen of Irish manufacture; and thus commenced the trade in that article

removed, and a direct and rapid communication be opened between Limerick and Tarmonbarry; and thus, by means of the Royal Irish Canal, with Dublin. The importance of attending to improving the navigation of the Shannon will be evident, when we consider that throughout its whole course, from its source in Lough Allen to its embouchure in the sea, this river is capable of being rendered navigable, that is, for the length of 240 miles; thus, with the connecting canals, forming an inland water communication, extending from Dublin to Limerick, and passing through the very heart of the country, and amidst some of its prolific mining districts.

The total length of canal navigation, in Great Britain, is estimated by Mr. G. Rennie as amounting to 2477 miles, of which 200 belong to Scotland. The river navigation in England and Wales is reckoned as 2036 miles, and in Scotland as about 200 miles; making a total of 4713 miles of inland navigation. In Ireland, the canal navigation is computed at 312 miles, and the river navigation at about 400; making a total of 712 miles.

These works, of which we have been taking a brief review, and which have thus opened a water communication with the most inland districts of the British Isles, are not more remarkable for their extent and grandeur, than for their general utility, the beneficial effects resulting from the establishment of canal navigation being felt in a greater or less degree by all classes of society. By this means the manufacturer is enabled to obtain both his materials and his fuel, with less labour and less expense; the farmer gains a ready means of conveyance for the produce of his land to the most profitable market; the merchant is enabled to extend his commerce, both by the facility thus afforded of collecting for exportation, greater quantities and varieties of goods from remote districts, and also of supplying such districts with articles of foreign produce; the prices of manufactured goods are consequently lowered, but more especially those goods for which there is the most general demand; and thus the benefit extends to almost every individual in the kingdom.

The formation of canals has been carried on upon a vast and extensive scale in North America. The mighty rivers which traverse that continent, and the great chain of lakes which penetrate far into the interior, afford natural advantages for inland navigation possessed by few regions. To render these fully available, connecting canals were, however, required; and, in some instances, these have been supplied on a scale of grandeur unrivalled in any other part of the globe. Thus, in the United States, the numerous rivers which cross the eastern territories have been connected by means of canals; and it is expected that a continued line of water communication from north to south, will ultimately be formed. A yet greater undertaking has been the formation of a water communication between the two great river systems, situated on either side of the Alleghany mountains. An insurmountable obstacle appeared to exist in that continuous mountain range; but the object has been effected by a canal 363 miles long, extending from the Hudson river, at Albany, to the Mohawk river, which falls into Lake Erie. This magnificent canal was completed in 1827. Other canals, of equal magnitude and importance, have also been undertaken in the United States, and are either completed, or in progress; among these, we can only pause to notice the *Chesapeake and Ohio Canal*, the design of which is to unite the Potomac river, at Washington, with the the Ohio at Pittsburgh, and the length of which is estimated at 360 miles, a tunnel, four miles in length, being required to carry it through the mountains.

The Canadian canals, although not on so grand a scale as those in the United States, are, nevertheless, by no means deficient in importance, forming, as they do, links connecting the great Canadian lakes, and thus opening a navigable water communication from the Gulf of St. Lawrence to the very interior of the continent. Of these, the principal is the *Welland Canal*, which overcomes the obstacle presented by the Falls of Niagara, and unites the lakes of Ontario and Erie. Its length does not exceed forty-three miles; but it contains thirty-five locks, and, owing to the nature of the

surface, it proved a very arduous undertaking. Its importance, however, more than compensates for any difficulties which may have been encountered in its construction. For, not only is navigation thus carried into the very heart of North America, but, by means of the Ohio Canal, which extends from Lake Erie to Pittsburg, water communication is opened from the Gulf of St. Lawrence to that of Mexico, forming with the river St. Lawrence, the lakes Ontario and Erie, and the rivers Ohio and Mississippi, a gigantic line of inland navigation, upwards of 3000 miles in length.

The benefits accruing from this inland navigation are strikingly shown by the improvements which have taken place, and are in progress, on the shores of the great Canadian lakes; and "it will be easily believed," observes Mr. Stevenson, "that, notwithstanding the secluded situation which they hold in the centre of North America, far removed from the ocean, and from intercourse with the world at large, their banks are no longer the undisturbed haunts of the eagle, nor their coasts the dwelling of the Indian. Civilization and British habits have extended their influence even in that remote region; and their shores can now boast of numerous settlements inhabited by a busy population, actively engaged in commercial pursuits. The white sails of fleets of vessels, and the smoking chimneys of numerous steamers, now thickly stud their wide expanse, whilst beacon-lights, illuminating the rocky shores with their cheering rays, guide the benighted navigator on his course."

CHAPTER XII.

SPRINGS.

Having formed some acquaintance with the leading features of hydrostatics and hydraulics, let us now turn our attention to water in its natural distribution on the earth's surface, whether in springs, torrents, waterfalls, lakes, inland seas, or in the

majestic main itself. To this portion of our subject, the term *hydrography* is usually applied.

We have already made some allusion to the beautiful and never-ceasing circulation of the waters of the globe, rising by evaporation from the ocean, as well as from smaller collections of water, and descending in the form of dew, rain or snow, to moisten and refresh the thirsty soil. The whole of the water which is thus borne up into the atmosphere, and descends again from thence, does not exhaust itself in watering the ground, a considerable portion having another office to perform, namely, that of supplying springs, rivers, and lakes, and more especially the former: for, although both rivers and lakes unquestionably derive some of their liquid contents *direct* from the atmosphere, the main supplies of the greater number of rivers are derived from springs.

Various opinions have been entertained, respecting the origin of springs, and various hypotheses suggested, to account for their occurrence. These need not, however, at present arrest our attention: the most generally received opinion, and that most consonant with the deductions of science, as well as with the phenomena presented in the natural world, being the same to which reference has just been made, namely, that their supplies are derived from atmospheric water, or, in other terms, from rain, snow, and dew.

The atmospheric water which falls to earth, is absorbed in three different ways. One portion, after performing the office of giving humidity to the soil, and imparting nourishment to plants and animals, re-ascends by the process of evaporation into the atmosphere. A second portion collects in rills on the surface of the ground, and drains off, according to the slope of the land, to the nearest pool, lake, or stream, thus augmenting the size of rivers, or of other collections of water. A third portion descends into the earth, finding an entrance either through porous beds, or through crevices and interstices in the rocks, until (as we have before seen in speaking of Artesian wells,) it meets with retentive strata, which arrest its further progress, and where it accumulates in subterranean reservoirs,

of greater or less extent, and at various depths; and from whence when it meets a natural outlet, it gushes forth in the form of a spring.

Although the portion of water which re-ascends from the ground to the atmosphere by the process of evaporation, is very considerable, it will be quite evident that since some of it is disposed of in other ways, it cannot be equivalent to the quantity which falls from thence, and that the latter must be derived from some other source; this source is the vast expanse of water, forming the ocean. Such being the case, it might be supposed that all islands would be furnished with more abundant supplies of rain, and consequently with more copious springs, than inland districts. We shall not, however, find that this will be borne out by fact; some islands being almost destitute of springs, whilst it is in the very interior of continents that the most magnificent rivers on the earth's surface, such as the Marañon, the Indus, and the Rhine, take their rise. Whence, then, we are naturally led to inquire, whence are the springs fed, by which these mighty streams are supplied?

Water, when raised into the atmosphere by evaporation, must, ere it will return to the earth in the form of rain or dew, become cooled, and thus condensed. When condensation takes place in the atmosphere, (and this may occur at greater or less elevations,) either from the coolness of the temperature, or from the influence of cold currents, drops are formed, and aqueous vapour, thus re-assuming the form of water, falls to the earth as rain or snow. When this condensation takes place almost immediately above the earth's surface, and the latter is of lower temperature than the air with which it comes in contact, dew is formed; and this will be copious, in proportion to the comparative difference of temperature between the earth and the superincumbent air. The cooler the surface, therefore, the more does it *attract* moisture, that is, cause it to be deposited as dew. The foliage of trees, and indeed, all vegetation generally, presents a cooler surface than bare or rocky soil; hence we find that well wooded countries, and even pasture lands, receive greater supplies of moisture than those which are deprived

of vegetation. Land, which is considerably elevated above the sea, has a much lower temperature than land situated at its level: a gradual decrease occurring in proportion to the elevation of the land above the sea: this being about a degree of Fahrenheit for every 656 feet. Elevated land, if other conditions be similar, will therefore necessarily be colder than land nearer the sea-level, and will accordingly more readily attract and condense moisture, than the latter; though, unless the elevation be very great, the nature of the surface will perhaps exercise greater influence in this respect, than the elevation of the land. Thus, a verdant and richly wooded island, although only slightly elevated above the sea, will attract and condense moisture in a much more considerable degree, than one of greater elevation, deprived of these advantages. The effects produced by vegetation in attracting moisture, are so strikingly exemplified in the past and present state of the island of Ascension, that we cannot do better than pause to consider this practical illustration of our subject.

The island of Ascension is about eight miles in length, and six in breadth. It possesses elevated plains or table-lands, varying in height from 1200 to 2000 feet above the level of the sea; whilst the peak, or highest point, has an elevation of 2870 feet; so that the whole island would appear of sufficient elevation to attract and condense moisture: an effect which, however, we shall find to have been produced in a very small degree, whilst the island was destitute of vegetation. This island is of volcanic formation, and when first discovered in 1501, nothing could be more desolate than the scene it is described as having presented. "When the first adventurer to this wild spot," observes Captain Brandreth in speaking of the island of Ascension, "explored his way over a wide plain of cinders and ashes, where no drop of water, and scarcely one evidence of vegetative principle could be discovered;—when he laboured up the steep and rugged mountain, and looked round on the withered aspect of the scene spread in solitude around him, he might have considered the spot as condemned to hopeless sterility, and regarded the sea-fowl that settled over the dark red hills near

the coast, as likely to remain the sole and undisputed inhabitants of these wild regions." Such *was* the aspect of the island of Ascension; and what is its present state? "The ships that have lately touched at this island," observes the same officer, "have, I believe, been readily furnished, not only with water, but fresh meat and vegetables to the extent of their demand." Let us inquire to what this remarkable change is attributable.

The most elevated part of the island, has, we have seen, a height of 2870 feet above the sea-level. This, when the island was first discovered, appears to have been nearly destitute of vegetation; but, even in this bare and rugged state, it presented a colder surface than the parts of the island nearer the level of the ocean. The consequence was, that some degree of moisture was deposited, and thus, decomposition of the ashes and other volcanic products, took place. A soil capable of sustaining vegetation was thus produced; plants adapted to thrive in such a spot, sprang up, and by their superior condensing power, increased the deposition of moisture; and yet further, by their decay, improved the quality of the soil, fitting it for the reception of other vegetable productions of greater utility. The highest portion of the island, therefore, soon became by far the richest, and by degrees a vegetable soil of from two to three feet deep has been formed, though accumulating in some of the hollows to a much greater depth. The progress of vegetation and the deposition of moisture have kept pace together, each having mutually promoted the other; and thus, a gradually increasing circle of fertility has been formed, commencing at the summit of the mountain, and spreading down its sides.

It is, however, only in the more elevated parts of the island, that the soil is of sufficient depth to admit of cultivation; but this tract has been cultivated, and the results have been most remarkable. Formerly "for months together, not a cloud would pass over the heavens, nor a drop of water fall, but *since the land on the mountains has been cultivated*, a gradual increase of rain has taken place, and seldom more than a day now passes over, without a shower or a mist on the mountain."

The consequence has been, that this island, once almost destitute of water, now affords abundant supplies. Nor is this happy result wholly without interest to ourselves; if not individually, at least, nationally. The greater number of the homeward-bound ships from the Cape of Good Hope and the East Indies, pass in sight of this island, and such of the latter as do not touch at the Cape, or at St. Helena, usually call here for supplies of fresh provisions and water. Its proximity to the coast of Africa, also renders it an admirable refitting and recruiting place for the shipping off the African station. The air of this island is remarkable for its salubrity, and the rapidity with which the men belonging to the African squadron recover, when brought there, is astonishing. After they are so greatly reduced by fever, as to be obliged to be carried on shore to the hospital, in a fortnight's time they are usually so much restored to health, that they are able to walk as well and as far as any man on the island.

Such being the importance of the island of Ascension, it becomes a matter of moment that an abundant supply of water should be at all times attainable. This was, however, by no means the case, until within a recent period. When Captain Brandreth visited the island in 1829, the supply of water was scanty and precarious. It depended partly on small springs, or dropping wells, in the limestone rocks which, in some parts of the island, form precipitous cliffs on the shores of the ocean; and partly on the rain that could be collected in casks, and a few old iron tanks. The island was also subject to occasional droughts, and under such circumstances, not only did the rain water altogether fail, but the springs in the limestone rocks afforded a most scanty supply. Some water, it is true, was obtained from the mountainous districts; carts drawn by oxen, being employed in the transport of this all-important article; but the distance from thence to George Town was about six miles, and it was a work of great labour to supply that place with three hundred and sixty gallons daily, a quantity, however, wholly inadequate to the demand; nor does it appear that there had been, at any time, a hundred tons of fresh water

in store in the island. Attempts were made to obtain a further supply, by boring in the lower districts of the island, but these proved quite unsuccessful.

In the year 1830, the island of Ascension was visited by a severe and long-continued drought. There were barely forty tons of water in store; the water-drips in the limestone rocks trickled down with a slow and mournful pace, and there appeared reason to apprehend the total failure of this scanty supply, for "the skies were glorious, but unproductive in their unclouded splendour." Boring, as we have just seen, had been tried wholly without success in the low lands; it was now determined to attempt the same process in the more elevated districts. The clouds and mists which hung upon the summit of the island, proved that the constant evaporation from the sea was arrested by the verdant high land, and there was every reason to conclude, that abundant supplies of moisture were deposited in that locality. A spot was therefore fixed upon at a considerable elevation, on the windward side of the island, and the process of boring commenced. The experiment fully succeeded. At the depth of twenty-five feet from the surface, a substratum of retentive clay was arrived at, and a spring gushed forth, which yielded, and has continued to yield, from four to five tons of water daily. And when Captain Brandreth revisited the island in 1835, he found abundance of water in store on the island, large tanks having been constructed at George Town, which contained 1000 tons of that liquid. The distance of this Artesian well from George Town, and the consequent difficulty of conveying the water from the mountain to that place, proved at first a serious obstacle to its free use; but, under the "firm and benign influence" of Captain Bate, (the commandant of the island,) a line of iron pipes nearly six miles in length has been laid down, extending from the mountain district to the town, passing, in part of its course, through a tunnel 600 feet in length, and communicating with a tank of sufficient capacity to hold 1700 tons of water, situated in George Town.

In the above interesting account, we find a clear explanation

of the origin of springs; both with regard to the formation of internal reservoirs, and as to the manner in which they receive supplies of water. In the first place, with regard to their formation: the simplest condition under which water is collected within the earth, is in superficial beds of porous earth resting upon a bed of clay. Such was the case in this instance. The stratum in which this valuable internal reservoir was found, consisted of a porous bed of volcanic matter, resting upon a retentive bed of clay. The latter stratum prevented the water from sinking to a greater depth, and hence an Artesian well was obtained in the upland districts, although none was met with in the lower parts of the island. In the next place, we distinctly perceive that the supplies of moisture are derived fróm the atmosphere, and that these supplies are more abundantly furnished in elevated, as well as in verdant districts, which may account for the frequent occurrence of copious springs in elevated regions. We here also meet with a complete refutation of a very fanciful hypothesis which has been started, and which supposes the waters of Artesian wells to be derived from the remaining liquid in which the aqueous, or water-formed strata, were formerly held in solution. Those who entertain this extraordinary notion, of course apprehend the speedy exhaustion of these reservoirs, where they imagine the water to have remained stationary for millions of years; for if these collections of water consisted only of ancient deposits, and not of continually accumulating supplies, all the artesian wells would soon cease to flow. From the instance just adduced, however, it appears quite evident, that such internal reservoirs are supplied by atmospheric moisture, and, therefore, when we sink an Artesian well, and thus obtain a spring of water, we only raise the perpetually accumulating treasure, from the interior of the earth to its surface, to be applied in various ways for the benefit of man, or of the other creatures of God's hand, or, perhaps, to flow into the ocean; but in either case, to be again raised by evaporation into the atmosphere, again to be condensed and descend to earth; nay, for aught we know, once more to accumulate in the iden-

tical internal reservoir, from whence it has been thus drawn forth.

But although districts covered with verdure, arrest and condense the moisture of the atmosphere, water does not pass into the interior of the earth through cultivated land. Indeed, it appears, that rain penetrates to a comparatively small depth in pasture or garden ground. Thus, according to some observations made by Buffon, it was found, that in a garden plot, the earth of which had remained untouched for years, the rain had never penetrated beyond the depth of four feet: whilst, according to other observations, the depth to which rain penetrates in ground covered with herbage, is never greater than two feet; and in a mass of bare earth, which had been exposed for fifteen years to all atmospheric changes, it was found, that not a drop of water had passed through, to the depth of eight feet. It must, however, be remembered, that all these experiments were made in *cultivated* ground; and soils, to be adapted for horticultural or agricultural purposes, must be formed of a proper admixture of earths, not being so stiff as to prevent the water from entering into the interstices, though at the same time sufficiently retentive, to prevent the water from percolating through its substance, and thus entirely draining off, and leaving it too dry. Light garden mould, when fully saturated with moisture, has been found to contain more than half its bulk of water. So large a proportion of this liquid is, however, by no means requisite for vegetation, but on the contrary, would prove injurious to many kinds of plants; and half of that quantity of water may be abstracted, without the ground being rendered unfit for the purposes of vegetation.

The surface of the globe is not, however, as we are well aware, covered in all parts with a bed of garden mould some feet in thickness; but many of the upper strata, like those just described in the island of Ascension, consist of porous beds, through which the water freely percolates. In other localities, again, we meet with bare rocks, the crevices and interstices of which, afford a free passage for the water to enter

into the interior of the earth. Thus, in some of the mines of Cornwall, which are situated among rocks of this description, the water accumulates in the deepest parts, only a few hours after it has begun to rain at the earth's surface. And in some other cases, even where such evident crevices do not exist, a rapid percolation of water is observable, and especially in springs issuing from chalk cliffs, in which the quantity of water is not unfrequently found to be greatly augmented, *immediately* after a fall of rain.

Granite and other impermeable rocks, through the substance of which water cannot penetrate, but among which it can only find entrance into the earth by means of fissures and crevices, which are usually of small extent, and rarely communicating with one another, seldom contain copious springs, because the internal reservoirs being thus isolated, receive no augmentation by the addition of neighbouring collections of water. In such formations, therefore, springs are generally numerous, but yield only small supplies of water.

On the other hand, owing to the basin shape frequently assumed by secondary rocks, to which we have already alluded in speaking of Artesian wells, in such formations natural springs are generally of rare occurrence, but very copious. Such is the case with the natural springs issuing from the chalk formation in this country. Chalk, as we have already seen, lies beneath the London clay in the London Basin, again itself resting upon an impermeable stratum, and forming, between the plastic clay and the gault, a mighty subterranean reservoir of water, from which the greater number of Artesian wells in the neighbourhood of London are supplied. The trough, or hollow, which forms the London Basin, is, if we may so express ourselves, lined with a stratum of chalk, which appears at the surface near the edges of this basin, of which, indeed, it, in some parts, constitutes the rim, rising in the form of chalk hills, and extending, on the other hand, from Hertfordshire to Wiltshire, and on the other, from the latter point to the vicinity of Folkestone on the coast of Kent. These chalk hills may be considered as the instruments for arresting

and condensing the atmospheric moisture for the supply of this vast internal reservoir. And whilst contemplating this no less remarkable, than admirable and beautiful provision for securing an abundant and never-failing supply of excellent water, how will the value of these flinty chalk hills be enhanced in our estimation! Before, we may, perhaps, it is true, have regarded them as so far useful, inasmuch as they afford in many parts excellent pasture for sheep; but when compared with the richer lands of our island, they may almost have appeared like so many unprofitable tracts, because incapable of advantageous cultivation. We now, however, may perceive the advantages arising from their *not* being covered with a rich soil, for were such the case, the water would not penetrate into the interior of the earth, but would be carried off in a great degree by evaporation, or drainage. We thus find that good arises out of apparent evil, and that what may have seemed disadvantageous to the well-being of the inhabitants of this tract of country, is in fact highly conducive to their benefit*.

The natural springs or outbursts from this grand reservoir in the London Basin, are (as we have seen is usual in secondary strata,) comparatively few; there not being above eleven in the whole area. According to Dr. Mitchell, there are four constant outbursts in Surrey, five in Kent, and two in Hertfordshire. Those in Surrey include the powerful spring near the church, below *Croydon;* that at *Leatherhead,* close to the Guildford road; the *Bourne Mill* stream near *Farnham;* and the source of the river *Mole,* near *Merstham.* The

Sullen Mole that hides his diving flood,

flows south of Ryegate to Dorking, below which town the bed

* The chalk formation in England, is not exclusively confined to this locality; but also extends into Suffolk, Norfolk, Lincolnshire, and Yorkshire. It also occurs in the district called the Hampshire Basin, in Dorsetshire, Hampshire, and Sussex. To the latter division belong the well-known chalk cliffs, extending from Brighton to Eastbourne. The chalk cliffs of Dover, and the noble rounded hills of the North Downs, are included in the London Basin. From the coast of Kent this formation extends into France in the district of Boulogne.

of the river is dry in summer; but an abundant subterranean stream flows in the interior beds of the chalk, and re-appears lower down. Occasional outbursts from this reservoir also occur in Surrey. To this class belongs the *Bourne*, near *Birchwood House*. During an outburst which took place in the spring of 1837, the water flowed in great volume to Croydon, and continued to do so for six weeks. Later in the same year, another rivulet burst forth in Gatton Park, between Merstham and Ryegate, and a third at Nonsuch Park, near Ewell. An outburst also occurred in the spring of 1842.

The constant outbursts from the chalk in the county of Kent, include the spring at *Orpington*, near St. Mary Cray; the *Holy Well at Kempering*, situated on the south side of the North Downs; the spring about a quarter of a mile to the west of *Sittingbourne;* the spring at *Birchington*, in the isle of Thanet; and the *Lyddon Spout*, in the cliffs between Folkestone and Dover.

In Hertfordshire, there are, as we have already mentioned, only two natural outbursts from this grand reservoir, and with both of these we have already in some degree become acquainted; these being the source of the *Chadwell*, and the main spring of the *Amwell*, which unite to form the New River. And it thus appears that the largest portion of the water brought into London by that channel, is derived from the same subterranean sheet of water, from whence the greater number of the Artesian wells in the metropolis and its vicinity, derive their supplies of that liquid.

The natural outbursts above mentioned in the London Basin, although very copious and highly important, are by no means equal in volume to some other springs which occur in different districts. The most copious spring in Great Britain is *St. Winifred's Well*, near Holywell, in Flintshire, which is said to throw up about 21 tons of water per minute, or 30,240 tons daily. But although the largest in our island, St. Winifred's spring is greatly surpassed by the far-famed *Fountain of Petrarch at Vaucluse*, which is described by Professor Traill as rising with great force in a cavern at the foot of a vast semicircular

St. Winifred's Well.

range of limestone hills, and forming *at once* the river Sorgue, capable at its very source of moving machinery, and almost immediately navigable. Even in the driest seasons, when the water is least plentiful, this spring throws up 4780 cubic feet of water per minute. After the melting of the snows, its produce is thrice as great, and the quantity of water issuing from this source in the course of the year, is estimated at about 530 millions of cubic feet.

To form such a spring, we must suppose, not only that subterranean *reservoirs* of water exist, but that actual subterranean *rivers* occur, flowing with considerable rapidity, and confined between impermeable beds, but ready to gush forth with impetuosity, when an outlet is afforded. That subterranean streams do exist, we have already met with an instance in part of the course of the river Mole; and to account for the occurrence of such a spring as that of Vaucluse, we have only to suppose a similar stream passing along internal natural tunnels, and not making its appearance at the surface of the earth, until it has acquired this great volume of water.

The phenomena presented by the celebrated fountain of *Nîmes*, in the Department du Gard, afford a yet further confirmation of the occurrence of rapidly flowing subterranean streams. This fountain appears to be supplied by more than one subterranean river. In seasons of drought, the product of this spring is sometimes reduced to 40 gallons per minute; but if a heavy fall of rain take place in one particular direction, to the north-west of Nîmes, at the distance of about seven miles from the town, though none should occur in its immediate vicinity, a very rapid increase in the volume of water is almost instantly perceptible in the fountain; and to its small jet of 40 gallons, one of about 570 gallons per minute has been known to succeed; it being thus evident, not only that it is supplied by a subterranean stream from that distance, but also that the bed of this stream must have a considerable inclination, to admit of its flowing with such great rapidity. Nor does this appear to be the sole distant source from whence this fountain is supplied; for if, as before, no rain should fall in its imme-

diate vicinity, and only at a much greater distance from Nîmes, still, however, in a north-west direction, a similar result is observed to take place, the volume of water being in this case also rapidly and considerably increased. It cannot, therefore, slowly percolate through a porous stratum, but apparently must enter the earth by means of crevices, and rush onwards until it finds an outlet in the fountain of Nîmes.

There appears, however, reason to suppose that in some instances, these subterranean rivers are not furnished by atmospheric water alone, but that they receive at least some of their supplies from small rivers, which are swallowed up entire, and which only again issue to the light of day, when an outlet is afforded them. We do not now speak of streams which, like the Mole, are lost for a time, and whose course may be subsequently traced, but of such as are wholly lost as external streams, so that their identity can no longer be recognised, but which probably re-appear in considerable volume, either as natural springs, in some rather remote district, or gush forth when artificial outlets are afforded by the construction of Artesian wells. Proofs of the occurrence of such phenomena are not wanting; fish, land and fresh-water shells, and fragments of vegetables, having been ejected with the waters both of natural springs and of Artesian wells, though these have had no apparent connection with any external stream or sheet of water. Thus, at *Rumke*, near Bochart, in Westphalia, the water of an Artesian well brought up with it, from the depth of 156 feet, several small fish, three or four inches in length, though the nearest streams in the country were distant several leagues from the spot. Again, near *Sablé*, in the department of La Sarte, M. Arago mentions that there exists, in the middle of a heathy tract, a spring which issues from a basin, or rather gulf, about twenty-five feet in diameter, the depth of which does not appear to have been ascertained. This gulf, which is known by the name of *the Bottomless Fountain*, occasionally overflows its ordinary bounds, at which time a vast number of fish are cast out. A similar phenomenon is presented near Vesoul, in the department of Haute Saone, in a spring called

the Fresh Well. After continuous heavy rains in summer and autumn, the water escapes with impetuosity from the mouth of the Fresh Well, forming an actual torrent, which spreads itself over all the surrounding country. This overflow usually only lasts for a few hours, and after such an outburst, tench are not unfrequently found scattered over the surface of the meadows, which have been inundated by the waters of the Fresh Well.

The same phenomenon has been exhibited in rather a singular manner in the *Fountain* of the *Place de la Cathédrale* at *Tours*. This fountain formed a jet d'eau of considerable height, which sent forth a stream of very clear water. In January, 1831, however, the vertical pipe from which this jet d'eau issued, was shortened about 12 feet, when the following singular phenomenon occurred:—The produce of the fountain was immediately considerably increased; and the water, previously beautifully clear, became turbid, whilst land and fresh-water shells, as well as fragments of vegetables, were thrown up from the depth of 364 feet. Among the latter, were some branches of a thorn bush, several inches long, which presented evident indications of having been immersed in water for a considerable length of time, whilst some other stems and roots, chiefly of marsh plants, as also seeds of various kinds, were in a state of preservation, which clearly indicated that they could not have been for more than three or four months in the water. Whence could they come? All these fragments resembled such as are frequently met with on the banks of small rivers and brooks: "there appears, therefore," as M. Arago has well observed, "abundant reason to conclude, that the subterranean sheet of water which supplies this fountain at Tours, derives at least some portion of its waters from an engulfed stream, and that they are not wholly furnished by percolation through porous strata;" for, had the latter been the case, it is evident that the shells and fragments of plants, could never have found a passage through the mass of rock, however porous might be its nature. It yet remains further to inquire, why this phenomenon should occur, when the pipe forming the outlet of

this jet d'eau was reduced in height. This may be satisfactorily accounted for on hydrostatic principles. The removal of twelve feet from the vertical pipe, so far lowered the orifice from whence the water of this fountain issued, that, owing to the consequent greater downward pressure exercised by the water in the supplying internal stream, or reservoir, the velocity with which the liquid poured, or spouted forth, would be augmented, and being also agitated, might become turbid, and bring up these extraneous substances, which evidently had been borne by the water from the banks of some river or brook, flowing on the earth's surface.

The distance to which subterranean streams occasionally extend, is proved by the occurrence of springs of fresh water rising from the bed of the ocean, in situations remote from dry land, and to which localities they must evidently have been conveyed by channels, situated beneath the bed of the sea. Thus, in the Bay of Bengal, about 125 miles from Chittagong, and nearly 100 miles from the Sunderbunds, which constituted the nearest land, Mr. Buchanan observed an abundant spring of fresh water which rose to the surface, and which must evidently have passed along a subterranean channel to that spot. In the seas near Tahiti, again, Mr. Bennett noticed several springs of fresh water rising from the midst of the ocean, at greater or less distances from the shore. "Their situation," he observes, "was marked by small eddies or whirls on the smooth surface of the sea, and upon some of them the natives place bamboos with apertures in their sides, through which the water flows as from a pump. When fishing in their canoes, it is not unusual for the natives to dive beneath the surface of the sea, and quench their thirst at the fresh-water springs." These submarine springs are prettily alluded to by Southey in the following lines:—

> The golden fountains had not ceased to flow;
> And where they mingled with the briny sea,
> There was a sight of wonder and delight
> To see the fish, like birds in air,
> Above Ladurlad flying.

Round those strange waters they repair,
Their scarlet fins outspread and plying,
They float with gentle hovering there:
And now upon those little wings
As if to dare forbidden things,
With wilful purpose bent.
Swift as an arrow from a bow,
They dash across, and to and fro
In rapid glance like lightning go,
Through that unwonted element.

The springs which have hitherto engaged our attention, although subject to occasional fluctuations arising from wet and dry seasons, are all *perennial*, that is, they never wholly cease to flow; a circumstance which may be considered as attributable to the great extent of surface, from which they derive their supplies of atmospheric moisture, and the consequent largeness of the subterranean reservoirs from whence they are furnished, which are, therefore, not subject to fail, even in the driest seasons. This is not, however, the case with all springs; many of smaller size existing nearer the surface, which are mainly dependent for their supplies on the atmospheric moisture which falls in their own immediate vicinity, and which, consequently, are neither so copious nor so permament as those before described. Springs of this class are usually formed in situations where retentive strata occur near the surface, and when the depressions are filled with gravel, sand, &c. Of this we meet with instances in some parts of the London Basin.

We have already seen that, in the London Basin, the atmospheric moisture which is collected by the chalk hills, penetrates into the earth at the rim of the basin, and passes *under* the clay, where a grand internal reservoir is formed. The only portion of atmospheric moisture which collects *above* the clay, is, therefore, that which falls upon the surface which this area actually presents to the vicissitudes of the seasons. Springs which take their rise in such situations will, accordingly, be liable to fail, should drought occur in that particular locality; and the more so, the less the depth and extent of

such a formation. It is, however, from springs of this description that most of the ordinary wells in the London Basin derive their supplies. They are usually termed *land-springs*, and the internal reservoirs by which they are fed, are, in many parts, not more than twelve feet deep; but in other localities they have been found to have a depth of sixty feet below the surface. And hence, it not unfrequently happens, that in dry summers, one well may fail, whilst another situated at no great distance, but which is supplied from a deeper source, continues, though in diminished volume, to yield a supply of water.

When a retentive soil, like the London clay, forms the actual surface, the water, instead of sinking into the earth, usually rests on the surface, rendering it damp; and if there be not a considerable slope in the ground, the water will remain stagnant at the surface, or accumulate in the small hollows, forming numerous lakes and ponds. The surface soil of Clapham Common consists of London clay, and hence the numerous ponds existing in that area, and the difficulty of draining it effectively. The upper stratum at Hampstead Heath, on the other hand, consists of a formation called Bagshot sand, which freely permits the water to percolate through its interstices, and hence the different character of that locality.

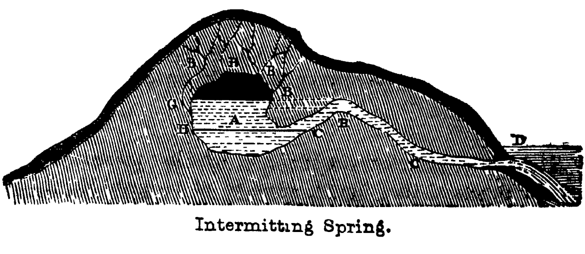
Gravelly beds, however, occur in many parts of the London clay formation in Surrey, and the facility with which water percolates through such strata, is clearly shown by the effect produced by the rise and fall of the tides in the River Thames, on the springs near its banks, between Richmond and London. The river, in this part of its course, passes through a gravelly bed, which rests upon the London clay; and the porous upper stratum, as the tide rises and falls, is alternately saturated with water from the Thames, or has the water drained off; thus causing the springs in that particular locality, regularly to ebb and flow with the rise and fall of the tide. This saturation of the gravelly beds, extends for several hundred feet from the banks of the river.

Other springs are met with which also ebb and flow, but

the rise and fall of which are not dependent on the tides. These are divided into two classes: *reciprocating*, or such as have a constant, but irregular flow; and *intermitting*, or springs in which the flow of water is entirely suspended for a time, but returns at intervals, with greater or less regularity.

Reciprocating springs appear to act somewhat in the same manner as the water ram; that is, to be caused by the confinement and compression of air in tortuous cavities, occurring in the subterranean channel of the spring; the air thus alternately dilating and becoming compressed, by the accumulating water, and acquiring, by this compression, sufficient elasticity to drive before it the resisting column of water. An example of such a spring occurs at *Giggleswick*, near Settle, in Yorkshire. In this well, the water will sometimes rise and fall a foot in ten or fifteen minutes; at other times, it will fall as much in four minutes, but usually requires double that time to regain its former height. The water then issues with great force, bringing with it particles of sand. Another reciprocating well occurs near Torbay, called *the Lay-well*, which is described as reciprocating sixteen times in an hour.

True *intermitting springs* are supposed to act on the same principle as the siphon. This will be better understood by referring to the accompanying cut, which is designed to represent a section of a hill containing such a reservoir. The only outlet for the water from this internal reservoir, is supposed to



Intermitting Spring.

be by a narrow channel, B, rising in a bending direction, so as to resemble a siphon in form. If the reservoir be not filled to the

height of the upper line, which, it will be observed, is on a level with the top of the siphon-like channel, the water will not begin to flow, but will only fill the inner branch of that channel, to whatever height the liquid may rise. When, however, it reaches that level, it commences to flow, on the hydrostatic principle of water preserving a level surface. And when this channel is once filled, the pressure of the atmosphere being thus removed from the water in this siphon-like outlet, but still continuing to act on the water in the reservoir, the water will be forced up this channel, (in the same manner that we have seen the flow of water maintained in a siphon,) and will continue to run, until the water is emptied, to whatever depth in the reservoir the orifice which communicates with this channel, may be situated. It then intermits, or ceases to flow, until the reservoir is again filled to the level of the top of the siphon-like channel, when it re-commences its operations. One of the most remarkable intermitting springs, is that called the *Bolder-born*, near Pader-born, in Westphalia. After flowing for twenty-four hours, it entirely ceases for the space of six hours; it then returns with a loud noise, driving the air before it, and in a stream of sufficient power to turn three mills very near its source. The intermitting spring of *Colmars*, in the department of the Haut Rhin, ceases to flow every seven minutes. The effect produced on the latter spring, by the great Lisbon earthquake in the year 1755, is deserving of notice. Notwithstanding its distance from the grand centre of this convulsion, it was so far affected, that it flowed perpetually instead of intermittingly, and continued to do so for eight years, after which it returned to its former state, and resumed its intermittent character.

These internal reservoirs of water, whether presented in the form of sheets of that liquid, situated at no great depth, and occupying the lower part of a porous stratum, resting on one of retentive character; whether in that of a body of water, of greater or less extent, accumulated in cavities in the interior of the earth; or whether in that of subterranean rivers; all equally

afford us an interesting view of the benefit accruing from the changes which the earth's crust has undergone. The consideration of these changes, doubtless, belongs more especially to geology; but some particulars are so closely connected with our present subject, that it will be well not wholly to omit them. We do not now refer to the agency of water in *accomplishing* these geological changes, but solely to the advantages which *have resulted* from the various changes and revolutions in the earth's surface, in respect to the especial point of their having been instrumental in providing means and receptacles, both for the accumulation of water in internal reservoirs, and also for its issue from thence in the form of natural springs or artificial fountains. For it appears, that "by the compound results of the original disposition of the strata, and their subsequent disturbances, that the entire crust of the earth has become one grand and connected apparatus of hydraulic machinery, co-operating incessantly with the sea and with the atmosphere, to dispense unfailing supplies of fresh water, in every part of the world that is adapted to man's habitation."

Had a porous stratum of uniform character, such as loose gravel, sand, or volcanic scoriæ, covered the upper surface of the earth, water would have freely passed through such a bed, and sunk to the lowest possible depth it could attain, and thus, in fact, would in great measure have disappeared from the face of the earth. On the other hand, had one impermeable species of rock, or stratum of clay, covered the surface of the globe, the atmospheric water, on descending to the ground, would, instead of entering into the interior, and forming permanent reservoirs, have rushed down the hills in torrents, only to occupy every hollow or depression which might have occurred, forming lakes or ponds, or else marshy swamps, according to local circumstances. By the changes which have, however, taken place in the earth's crust, the porous and retentive strata have been so adjusted and superimposed, that, although in some instances, impermeable strata do exist at the surface, these are only limited to small areas, and do not affect the grand whole; and whilst the permeable strata, which, like the chalk

hills of the London Basin, permit the free ingress of water, this is prevented from sinking below an advantageous depth, by the clay stratum on which it rests, and secured from making its escape, as well as from evaporation, by the superincumbent bed of clay; for, in fact, were this sheet of water not confined by the impermeable London clay, instead of a subterranean reservoir, ready to be applied to our benefit, a vast lake would occupy the whole of the lower part of the London Basin, in place of the busy metropolis and its extensive suburbs. A further instance of the advantages arising from the disturbances which have occurred in the earth's crust, is afforded by the basin-shaped arrangement of the large valley called the London Basin; the elevation of the chalk, and its thus presenting a surface to the atmosphere, appearing to be due to some convulsion or revolution of the earth, not perhaps sudden and violent, but apparently attributable to a slow and gradual process, which has caused it to assume its present form, which is so peculiarly adapted to favour the accumulation of water in this internal reservoir, and its preservation in a pure state.

The springs, or issues of water from these internal reservoirs, are also much facilitated by another geological phenomenon, likewise originating in the disturbances and dislocations which have taken place in the earth's crust, namely, the faults, or fractures, which intersect the strata. These fissures, as we have before seen, if they become filled with clay, arrest the progress of the water in that particular direction, and cause it (according to the elevation of the source from whence it originally proceeds,) either to rise to the surface, or to take a lower course, forming perhaps a subterranean reservoir. These fractures or faults, are thus of vast importance in the economy of nature; for, whilst they prevent the water from flowing in excessive quantities, where its presence would perhaps only be detrimental, they are of the greatest service in arresting it in its course; thus being instrumental in treasuring up this valuable liquid for puposes of utility, by causing a series of springs at the surface, ready either to form rivulets, and brooks, and rivers, or, if in smaller quantities, to supply the wants of man. A series of springs

not unfrequently occurs along the line of a fault, giving notice of the fracture that has taken place, and of its particular direction.

There are two systems of springs which have their origin in faults. The one system is supplied by the water *descending* from more elevated strata adjacent to a fault, by which the liquid is simply arrested, and diverted to the surface in the form of springs, of greater or less volume according to circumstances. The other system is maintained by water *ascending* from below, and derived from porous strata, which, at their contact with the fault, are often situated at a great depth; the water in such springs being conducted to this depth from a higher level, either by a small subterranean stream, or by percolation through the porous bed itself, the liquid continuing to flow downwards until its progress is arrested by the impermeable wall formed by the fault. And, did not this interruption occur, the water might continue to flow in a downward direction, until wholly engulfed in the interior of the globe; but being thus arrested, it rises on hydrostatic principles nearly to the same level as that from whence it descended.

"Thus," observes Dr. Buckland, "in the whole machinery of springs and rivers, and the apparatus that is kept in action for their duration, through the instrumentality of a system of curiously constructed hills and valleys, receiving their supplies *occasionally* from the rains of heaven, and treasuring it up in everlasting storehouses, to be dispensed *perpetually* by thousands of never-failing fountains; we see a provision not less striking than it is important. So, in the adjustment of the relative quantities of sea and land, in such due proportions as to supply the earth by constant evaporation, without diminishing the waters of the ocean; and in the appointment of the atmosphere to be the vehicle of this wonderful and unceasing circulation; in thus separating these waters from their native salt; (which, though of the highest utility to preserve the purity of the sea, renders them unfit for the support of terrestrial animals and vegetables;) and transmitting them in genial showers to scatter fertility over the earth, and maintain the never-failing reservoirs

of those springs and rivers by which they are again returned to mix with their parent ocean. In all these circumstances, we find such evidence of nicely-balanced adaptation of means to ends, of wise foresight, benevolent intention, and infinite power, that he must be blind indeed, who refuses to recognise in them, proofs of the most exalted attributes of the Creator."

CHAPTER XIII.

MINERAL SPRINGS.

We have seen that water in the purest form of any that Nature presents, namely, atmospheric water, not unfrequently contains some admixture both of organic and inorganic matter: we have also seen that all springs, even those which appear the purest, are impregnated with some foreign ingredients, which, being in a state of solution, are so intimately blended with the water, that they do not affect its clearness, while they render it, when they are not in too great proportion, more agreeable to the taste, and more nutritious than rain water. When such foreign ingredients are met with in great abundance, they form *mineral springs.*

The ingredients held in solution in mineral springs, include a great variety of substances, but those of most frequent occurrence, are carbonate of lime, carbonic and sulphuric acids, iron, silica, magnesia, alumina, and common salt; besides petroleum and its various modifications, such as mineral pitch, naphtha, and asphaltum. Among the less predominant substances, are muriatic and boracic acids, manganese, zinc, strontia, barytes, potass, lithia, ammonia, iodine, and bromine. It is worthy of remark, that the substances with which mineral springs are impregnated, correspond remarkably with those evolved in a gaseous state by volcanos. Many of these springs also are *thermal,* or hot. They make their appearance at the surface, through various kinds of rock; but are of most

frequent occurrence in volcanic regions. When met with in situations remote from the neighbourhood of active volcanos, their site usually coincides with the position of some great derangement in the strata; a fault, for example, or great fissure, which may be considered as indicating that a channel of communication has been opened with the interior of the earth at a former period, by some convulsion which has occurred in that particular locality, and which has originated in igneous action.

Mineral waters, commonly so called, and which owe their importance to their utility to man, either in their application to medicinal or to economical purposes, may be divided into four classes: 1, *acidulous*, or such as contain carbonic acid; 2, *chalybeate*, or springs holding in solution either the carbonate or the sulphate of iron; 3, *sulphureous*, or springs containing either sulphuretted hydrogen, or sulphuret of lime, &c., and which are distinguished by their repulsive smell; and 4, *saline*, or springs holding in solution a considerable proportion of neutral salts, which render them hard, and impart to them a disagreeable taste, also unfitting them either for a beverage, or for culinary purposes.

Acidulous waters present a sparkling appearance, which they owe to the presence of carbonic acid gas. This gas is very plentifully disengaged from springs in almost all countries, but more particularly in the vicinity of active or extinct volcanos. It has the property of decomposing many of the hardest rocks, with which it may come in contact, especially such as contain felspar, (to which class granite belongs,) a circumstance which may be attributed to the alkali which always constitutes part of the felspar, and with which the carbonic acid enters into combination, and which being thus removed, the remaining portion of the rock crumbles to pieces. Carbonic acid gas also contributes to the solution of calcareous matter, and renders the oxide of iron soluble in water. Acidulous waters, therefore, in addition to carbonic acid gas, almost always contain some earthy or saline ingredients. Of this we meet with instances in the waters of

Tonbridge, *Pyrmont*, and *Seltzer*, which, the latter especially, owe their refreshing and sparkling qualities to the carbonic acid gas they contain.

Since carbonic acid gas is invisible, it may pass unobserved, unless it should accumulate, when its effects are shown by its power in extinguishing a candle, or even causing death. This noxious gas has been found to issue with considerable force from one particular stratum of the chalk, in the London Basin. On sinking wells into that stratum, it was met with at various depths, apparently dependent on the undulations in the stratum. Thus, it was evolved from a well near Epsom race-course, at the depth of 200 feet; and from one at Norbury Park, at the depth of 400 feet. At Bexley Heath, this gas rushed out, and extinguished the candles of the workmen; whilst fatal effects have resulted from it in other places.

But although carbonic acid gas, in its free state, is thus deleterious, it is by no means injurious when present in water, and in fact adds greatly to the refreshing qualities of that liquid. Water, by being boiled, is deprived of this gas; and hence the dulness and insipidity of this liquid, when it has undergone that process, in comparison with water fresh from the spring. Water, saturated with carbonic acid gas, such as Seltzer water, sparkles when poured from one vessel into another. When it is in great abundance in a spring, the latter is observed to bubble up, as though it were boiling. A remarkable spring of this description is mentioned by Mr. Hamilton as occurring in Asia Minor, near *Kiz-hisar*, the ancient Tyana, and around which a classical interest is thrown, on account of its being mentioned by Greek and Roman authors, who speak of it as the *Fountain of Asbamæus*. "Ammianus," observes Mr. Hamilton, "says there is a fountain which rises in a marshy plain near Tyana, which swells with the quantity of water, and again disappearing, never overflows its banks. Philostratus says, that near Tyana is the fountain of Asbamæus, sacred to Jupiter, which rises very cold, but it bubbles up exactly like a boiling caldron." "The apparent discrepancy of these two accounts," continues Mr. Hamilton,

"vanishes on seeing the real phenomenon, which perfectly bears out both descriptions." This fountain, when visited by Mr. Hamilton a few years since, consisted of "a small lake or pool, about thirty or forty feet in diameter, of turbid brackish water, which appeared to be boiling up all over, but particularly in the centre, where a violent jet of water rose to a height of nearly a foot, and about a foot and a half in diameter, with considerable noise. Notwithstanding this quantity of water, which is constantly boiling up, the lake never rises or overflows its banks, nor does any stream of water escape from it, although the ground around is perfectly flat." The above account is not less interesting from the example it affords of the advantages arising from modern scientific researches, in elucidating obscure, and apparently almost incredible passages, occurring in ancient authors, than from the proof we here find, of the permanency of this remarkable spring. Marcellinus Ammianus flourished towards the close of the fourth century of the Christian era, and Philostratus about a hundred and fifty years earlier; we may therefore reasonably conclude that the fountain of Asbamæus has for 1600 years, and probably for a much longer period, continued to exhibit phenomena precisely similar to those which have been recently observed.

The carbonic acid gas contained in springs, usually becomes dissipated, when the water is exposed to the action of the atmosphere. A small river in South America, however, a tributary of the Magdalena, and which rises in a volcanic mountain, has its waters so greatly impregnated with this gas, that the Spaniards call it *Vinagré*. This stream in its descent to Popayan forms a highly picturesque waterfall, called the cascade of Vinagré.

Chalybeate springs, properly so called, are such as contain oxide of iron; the term is, however, occasionally applied to springs containing other substances. The iron in chalybeate springs is usually combined with various salts; and some of these springs contain a considerable portion of carbonic acid, thus combining the properties of this and the former class of

springs: these are denominated *acidulated chalybeate springs.* Of the latter description is the well-known spring at *Tonbridge Wells;* whilst the small chalybeate spring situated close to *Brighton,* belongs to the former class. In some chalybeate springs, of which that at Tonbridge Wells forms an instance, a red ferruginous matter is observed to be deposited by the water, so that the course of the stream may be traced by the discoloration of the rocks and herbage among which it passes, whilst it binds the sand and gravel into solid masses. On close examination, it will be found that this colouring matter floats on the surface of the water when left to stand, and is deposited on the surface of the ground, when the liquid sinks into the earth. Professor Ehrenberg, to whom we are indebted for so much curious and interesting, as well as important information, respecting both recent and fossil infusoria, has discovered in some chalybeate waters which he examined, that this red ferruginous matter is composed of the outer sheaths or coverings of multitudes of a species of infusoria, called the gaillonella, which appears to possess the singular property of secreting oxide of iron as well as silica; and the Professor supposes that the formation of bog iron-ore may be attributable to the existence, and subsequent decay, of myriads of these animalcules*. Such animalcules are adapted to thrive only in chalybeate waters, in which iron is present, a substance unsuited to the nourishment of the great majority of animals: "As if," observes Professor Daubeny, "as if it were intended that there should be no class of inorganic productions, which did not minister to the wants, and favour the production of a corresponding order of organized creatures†." And, when we

* Probably some of our readers may be familiar with the fact, that the chalybeate waters of Tonbridge Wells, if left to stand in a glass, or cup, for twenty-four hours, will exhibit on their surface a scum, presenting a brilliant and almost golden appearance, but which, if left longer, assumes a ferruginous tint. It seems more than probable, that this substance may consist of similar remains with those described by Professor Ehrenberg; but we are not aware that researches have been made on the subject.

† The recent researches of an eminent continental chemist, appear to lead to the conclusion that iron is more essential to the existence of the higher

consider that iron is present in the formations of every geological era, acting as a colouring and cementing principle; we cannot but be led to inquire whether in fact such effects may not have been produced by these infusoria, which thus would appear to have been largely instrumental in diffusing over the surface of the globe this most useful of all metallic substances.

Sulphureous springs are so named, because they contain sulphur, which usually occurs in the form of sulphuretted hydrogen, or of sulphate of lime. Sulphuric acid in a free state, (that is, not in combination with any other substance,) is only met with in springs connected with volcanos, from which, according to Dr. Daubeny, such springs evidently derive their peculiar properties. The sulphureous springs of this country are potent, and owe their qualities to sulphuretted hydrogen. Such are the springs of *Harrowgate*, *St. Bernard's Well*, near Edinburgh, &c. The same permanency which we have noticed as occurring in the fountain of Asbamæus, seems in a similar degree to be the attribute of the sulphureous waters of Asia Minor; for the hot springs of *Bithynia*, which modern travellers describe as impregnated with sulphuretted hydrogen, appear from the accounts of Greek writers to have been similarly constituted nearly 2000 years ago. Sulphureous springs containing sulphate of lime, or gypsum, are of comparatively rare occurrence. The springs at *Baden*, near Vienna, may be mentioned as examples of this class of springs. The largest of these, the *Haupt-quelle* or *High-well*, supplies 40,950 cubic feet of water daily, which deposits a fine powder, consisting chiefly of sulphate of lime.

Saline springs may be divided into two classes; brine springs and medicinal salt springs.

Brine springs contain in greater or less proportion, chloride

animals than had previously been supposed. "From the never-failing presence of iron in red blood," observes Professor Liebig, "we must conclude that it is unquestionably necessary to animal life."—LIEBIG's *Animal Chemistry*.

of sodium, or common salt, an article of primary importance to mankind. This is usually combined with some other ingredients, such as muriate of magnesia, muriate of lime, and sulphate of soda; and in some salt springs iodine and bromine occur; these ingredients being the same as those that exist in the waters of the ocean, imparting to them their bitterish salt taste, and briny qualities. So great is the quantity of chloride of sodium in some of these brine springs, that they yield one-fourth of their weight in salt; they are, however, rarely met with so largely saturated.

Brine springs appear to derive their saline properties from passing through subterranean masses of salt, and are of most frequent occurrence in the marls belonging to the formation distinguished by geologists, as the new red sandstone group. The subterranean depositories of salt in this country, do not appear to extend in a connected stratum, but usually occur in detached patches. *Droitwich*, in Worcestershire, has long been celebrated for the production of salt from its brine springs. These springs are known to have flowed for more than 2000 years; and the quantity of salt they must have carried into the Severn, cannot but be enormous. The richest of these springs was not, however, discovered before the year 1725. In the latter spring, a hard bed of gypsum occurs, at the depth of from thirty to forty feet below the surface, and through this a bore has been made, thus affording an outlet for this subterranean river of brine, which flows over a bed of rock-salt, the depth of the water being about twenty-two inches. The brine rises rapidly through the aperture, and is pumped into a capacious reservoir, from whence it is conveyed into boilers for evaporation. The brine of this spring, is considered superior in purity to that of any other in this country, and produces annually about 700,000 bushels of salt.

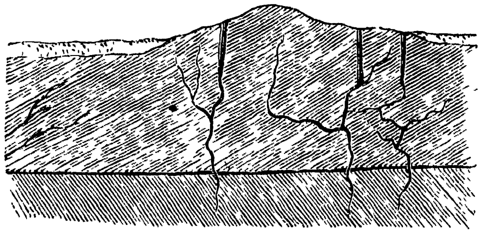
A remarkable brine spring is described by Professor Forbes as occurring in Bavaria, about a mile from the town of *Kissingen*. This spring, which rises from a bore made in the year 1822, the depth of which is about 200 feet from the surface, combines, with the characteristics of a brine spring, those also

of acidulous and of intermitting springs. It discharges carbonic acid gas in volumes almost unparalleled by any other spring, keeping the water (in a shaft, the diameter of which is eight feet,) in a state resembling turbulent ebullition. About five or six times in the course of the twenty-four hours, however, the discharge of gas suddenly stops; and in a few seconds the surface of the well is calm. The flow of the water, which amounts to forty cubic feet per minute, also stops, nay, the water actually recedes in the shaft, and altogether subsides for about fifteen or twenty minutes. It then rises again; the water appears first, and quite suddenly, but the gas gradually increases in quantity, until, after the lapse of three-quarters of an hour, the shaft is as full, and in the same state of apparent ebullition, as at first. The state of greatest discharge continues with little variation, for three or four hours, though by no means with absolute regularity. This very remarkable spring has experienced little or no alteration in the phenomena it exhibits, since it was first brought to light in 1822. Within a short distance, another bore has been made, and another spring obtained, of nearly similar character. Professor Forbes considers that, with the sole exception of the Geysers of Iceland, the salt spring at Kissingen presents the most singular phenomenon of its kind in Europe.

Medicinal salt springs usually contain a considerable portion of neutral salts, such as sulphate of soda, carbonate of soda, sulphate of magnesia, &c., which impart a disagreeable taste to the waters. They appear to have a similar origin with brine springs, but to acquire their additional properties from the various strata through which they pass, before arriving at the surface of the earth. Of this the *Cheltenham waters* may afford us an example.

The town of Cheltenham is situated on the species of rock called lias, which chiefly consists of a bluish clayey limestone. Beneath this, lies the new red sandstone, among the marls of which, as we have just seen, is situated the grand depository of rock salt. The Cheltenham mineral

waters, as the accompanying diagram will show, have their origin in the latter formation, deriving from thence their



Cheltenham Spring

saline ingredients, which, however, undergo various modifications in their passage through the lias. The principal constituents of the Cheltenham mineral waters are, chloride of sodium (common salt,) and the sulphates of soda, and of magnesia, all of which, together with some other ingredients in smaller quantities, they derive from the red marl. The lias, through which these springs subsequently pass, is, however, full of iron pyrites, or sulphate of iron, and the consequence is, that, in their passage through that stratum, certain chemical changes are effected in the ingredients contained in the waters, which thus acquire their celebrated medicinal qualities. It therefore appears that these springs at their greatest depths, are mere brine springs, and if an Artesian well were to be formed, penetrating to the red marl, and having its bore lined with a pipe, so that the water should not come in contact with the lias, the water obtained, in all probability, would not possess more medicinal properties than the brine springs of Droitwich.

Some saline springs, *apparently* containing little, besides a weak solution of common salt, have long been celebrated for their medicinal properties. Of this description is the *Moira brine spring*, near Ashby de la Zouch, in Leicestershire, which, for a considerable length of time, has been much used, both in

baths, and also taken internally, with considerable success. "Chemists," observes Dr. Daubeny, "may often, in the pride of half knowledge, have smiled at the faith reposed in the water of *Ashby de la Zouch*, and of *Kreutynach*, in the Palatinate, which until lately appeared to be little more than a mere saturated solution of common salt. But the advance of science has shown that these two springs are precisely the ones most fully impregnated of any perhaps known with salts of bromine, and therefore most highly charged with the properties of that active principle."

In the same manner, certain salt springs in *Piedmont* had acquired, from time immemorial, a reputation for the cure of goitre, which the nature of their known mineral contents could not explain. Recent analysis has, however, shown, that these springs contain a small quantity of iodine, the very principle which has of late years been applied, with great success, as a remedy for that singular disease.

Dr. Daubeny also mentions that M. Boussingault has observed the remarkable fact, that the inhabitants of such provinces as are provided with salt containing iodine, are not affected with goitre, whilst in other localities, where the salt is destitute of that principle, the disease is endemic. It is not, however, to be supposed, that the use of salt destitute of iodine is sufficient in itself to produce goitre, but rather that its presence may prevent the liability to this disease, under circumstances which would otherwise have led to its development; for, in fact, iodine is absent from some of the strongest brine springs of this country, especially those of Droitwich.*

* The prevalence of this disease in particular districts has been generally attributed to the nature of the water which forms the beverage of the inhabitants, and it has long been a vulgar notion, though formerly derided by men of science, that goitre arose from drinking snow water, whilst others, with apparently less reason, have attributed it to the humidity of the climate, and others again, to the use of water rising from calcareous rocks, such as chalk, limestone, &c., owing to the earthy particles contained in the liquid. The recent researches of M. Boussingault appear to throw much light on the subject; and since the result of his investigations, and the simple remedy proposed to avoid the evil, cannot be made too generally known, this brief notice

There is a class of springs very common in some countries, though scarcely occurring at all in England, which owe their peculiar properties to the presence of soda, either in the form of the *carbonate*, or the *sulphate of soda*. Of this description is the celebrated spring at *Carlsbad*, which contains both these salts. The vast quantity of alkali thrown out in the course of a single year by this spring is remarkable: it yields annually about 20,000,000 cubic feet of water, and it has been calculated that this quantity of the Carlsbad waters contains more than 13,000,000 pounds of carbonate of soda, and about 20,000,000 pounds of sulphate of soda*.

will not be here out of place, closely connected as it is with our present subject.

M. Boussingault's researches were carried on in the Andes, where the disease greatly prevails; and he commences by showing, that the goitre of that elevated region, can neither arise from the humidity of the climate, nor from the nature of the earthy ingredients of springs, but apparently is attributable to the use of melted snow as a beverage. This he ascribes to the absence of the quantity of air usually present in good drinkable water; for, he has observed, that persons who habitually employ as their beverage, water devoid of its due proportion of air, (whether that deficiency be owing to the circumstance of its being obtained immediately from the melted snow of the mountains, or to any other cause,) are subject to this disease, whilst persons who take the precaution of *aerating* water before drinking it, escape the deformity. The process of aerating water may, under ordinary circumstances, be effected by merely exposing it to the atmosphere, for thirty or forty hours previous to using it. For the same reason, a river which at a high level appears to produce goitre, has no such tendency at a lower one; that is, so soon as its waters have become duly aerated in their descent, by exposure to the atmosphere. In like manner, water which rises from calcareous rocks, or which has become stagnant in lakes or ponds, if the surface of the latter be covered with a film or scum, has a tendency to produce goitre, not from the presence of earthy ingredients, or of other foreign matter in the liquid, but from the absence of the requisite and usual quantity of air.

* The anti-inflammable properties of a solution of carbonate of soda, are so remarkable, and apparently might be rendered so useful in many cases, that no apology is required for the insertion of some notice of the subject in this place. According to some experiments made by Mr. Prater, it appears that if wood, paper, linen, calico, &c., be immersed for a certain length of time in a solution of carbonate of soda, it will be rendered *uninflammable*, that is to say, will not burst into a flame. "Wood," observes Mr. Prater, "should

In addition to the mineral springs already noticed, we meet with *calcareous springs;* or such as hold carbonate of lime in solution; *siliceous*, or springs containing silica, or flint; and *bituminous*, or such as are impregnated with petroleum, mineral pitch, or naphtha.

Calcareous springs, or springs highly charged with calcareous matter, are not of unfrequent occurrence, and present many phenomena of great interest. They are most usually met with in limestone rock, from which they derive their calcareous ingredients. Water has the property of dissolving the calcareous rocks over which it flows; and hence, even at the earth's surface, a fall of rain on such rocks carries a certain proportion of this earth into every little rivulet or pond in its vicinity. The waters of the latter thus become impregnated with calcareous matter; and by this means a supply of carbonate of lime is provided for the *testacea* or shell-fish, inhabiting such localities; this substance being required to assist them in forming their shells; all shells being composed of two constituent parts, the one consisting of animal matter, and the other of particles of carbonate of lime. The action of rain-water upon calcareous rocks, is due to the presence of carbonic acid in the water; but, as we have already seen, many springs hold in solution a much larger proportion of carbonic acid than is contained in

remain a week or ten days immersed in a saturated solution of it; for calico or linen, twenty minutes, and for paper two or three hours at furthest, is sufficient. If either of these be dried after such immersion, and then put into the flame of a candle, they turn black, but do not take fire, and, on being removed from the candle, they do not, like tinder, continue to keep alight. . . No great or *sudden* destruction of property which had been prepared by this solution could take place." The grand objection to preparing wood, &c., by immersion in such a saline solution, is, that all such saline impregnations are completely removed by the application of water, and yet sooner, by that of soap and water. This objection applies to the floors of dwelling-houses, and to articles of clothing. Mr. Prater, however, considers that this mode of rendering substances uninflammable is more particularly adapted for practical application to all offices and premises, in which, from the trade pursued, or the number of documents kept in paper, the risk of fire is increased; as also to ships, and particularly to steam-boats, and we may also add, to churches, and all places of public resort.

rain-water; so that, when such waters come in contact with limestone rocks, they dissolve a far greater quantity of calcareous matter than rain-water will effect. When, however, the carbonic acid gas becomes dissipated in the atmosphere, the water being no longer capable of holding the lime in solution, the mineral ingredients fall to the earth, and are deposited either in the form of *tufa*, called also *calc-tuff*, which is an uncompact, porous rock, or in that of *travertin*, which is usually hard and semi-crystalline, forming a solid limestone rock. Such power has water, even in its most quiet operations, to change the surface of the earth, bearing down the calcareous matter from one spot, to deposit it in another; thus, by sure, but gentle means, wearing away the solid limestone rock; and by an equally gradual process, forming a new rock, not inferior, perhaps, in hardness, to that from which the materials were derived. Whilst this deposition of calcareous matter is in progress, it not unfrequently happens, that plants growing near the spot, and other substances, become encrusted with, and sometimes embedded in the tufa, or travertin, and thus apparently converted into stone; in which state they may be permanently preserved; and from this circumstance, these springs are commonly designated *petrifying*, but more properly, *mineralizing springs*.

The *Dropping Well at Knaresborough*, in Yorkshire, forms an example of a calcareous spring in our own country. This remarkable spring, which is situated on the south-west bank of the river Nid, rises at the foot of a limestone rock, and after pursuing its course for the distance of about sixty feet in the direction of the river, spreads itself over the upper surface of a crag, or projecting mass of rock, from the under side of which the water falls in the form of a shower, dropping with considerable rapidity, the height from the ground being about thirty feet. The average discharge is about twenty gallons per minute. The water is very cold, and, as it falls to the ground, a deposition of carbonate of lime takes place, which encrusts any substance on which it may rest, and which forms the porous rock called tufa.

The phenomenon of the formation of stalactites and stalagmites by a dropping well of this description, is displayed on a grand scale at *Sansadarrah*, in the Himalaya Mountains. The situation of this place is most picturesque, surrounded as it is on all sides by hills which attain the elevation of 5000 feet, and which are clothed to the very summit with vegetation. The rock of Sansadarrah, through which the water drips, extends like the roof of an open piazza, for the length of about 150 feet, overhanging a depression, or basin, which is situated at a considerable depth below it. The dropping-well is formed by a small stream, which is a remote tributary of the Ganges, and which flows down the sides of the adjacent mountains. This stream, when it reaches the edge of this precipice, instead of forming a cascade, is absorbed by the porous rock, through which it filters, and falls into the basin in a perpetual shower. The ceiling of this cavern is covered with beautiful stalactites, and in some parts of the basin, stalagmitic encrustations abound, which, meeting the stalactites, present the appearance of clusters of pillars supporting an edifice.

> On the roof
> Large growth of what may seem the sparkling trees
> And shrubs of fairy land: * * *
> * * * embossed and fretted wild
> The growing wonder takes a thousand shapes
> Capricious, in which fancy seeks in vain
> The likeness of some object seen before.

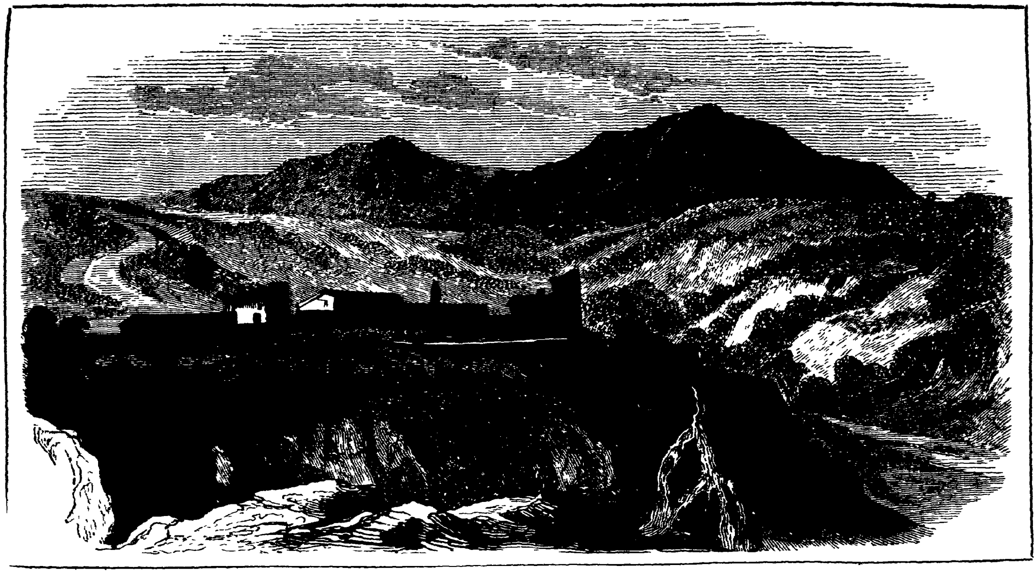
Calcareous springs are very numerous in Italy, especially in the districts bordering on the Apennines. One of the most remarkable examples of the rapid precipitation of carbonate of lime, occurs at the hill of *San Vignone*, iu Tuscany, situated at a short distance from Radicofani, and only a few hundred yards from the high road between Sienna and Rome. The water of the spring of San Vignone is hot, has a strong taste, and is usually of a bright green colour. So rapid is the deposition of calcareous matter near the source of this spring, that at the bottom of a conduit-pipe provided for conveying its waters to some baths, a mass of solid travertin, six inches in depth, is

formed every year. This rock is generally white, and in some parts so compact and hard, that it forms an excellent building stone.

On another hill, not many miles distant from that just mentioned, are situated the celebrated baths of *San Filippo.* The water which supplies the baths, falls into a pond, where it was found to have deposited a solid mass, thirty feet thick, in the course of about twenty years. The lapidifying property of this spring has been applied to the manufacture of medallions in basso relievo. The water, being first freed from some of the coarser parts of the mineral it contains, the moulds from which the casts are to be taken, are so placed, that they may receive an equable and continued fall of water, in the form of an artificial shower. As the water evaporates, the deposition takes place; and the moulds are exposed to this action of the water, for a greater or less period, according to the depth of the impression and size of the cast to be taken off, and the consequent thickness of deposit required. Ten or twelve days have been found sufficient to form one of small dimensions, but for a cast of larger size, three or four months are sometimes required. This spot has been celebrated from the most remote period, for its mineral waters, which, from the ruins of various edifices, and from the medals occasionally found in that locality, appear to have been used as baths by the nations of Etruria, and also by the Romans.

So vast are the deposits of travertin in south-western Italy, that this substance has for centuries constituted the usual building material in that region, and it appears that the ancient temples, as well as the gorgeous palaces, and more modern churches of Rome, and, indeed, the whole of the streets and squares of this once superb city, are built of concretionary limestone, which has been deposited by calcareous springs.

The *Rio San Pedro*, which forms the national boundary between the states of Mexico and Central America, is remarkable for the lapidifying power of its waters, which they possess in a most extraordinary degree; and the numerous reefs which



Baths of San Filippo.

occur in its stream, are said to be entirely formed of petrified or mineralized trunks of trees.

The formation of the lighter rock, called *calc-tuff* or *tufa*, is described by Colonel Monteith as occurring on an extensive scale in Azerbijan. Not far from *Cherak-Tcha*, are the ruins of a palace, erected by Suleiman, one of the first caliphs of Bagdat. Among these is a quadrangular structure, built round a natural basin, above 200 feet in diameter, and presenting a singular phenomenon. The water in this basin appears to be agitated by a strong spring; but on a nearer approach, this is found to be occasioned by carbonic acid gas, forcing its way through the water. The water appears to contain an unusually large proportion of calcareous matter, and the basin from whence it issues, which is 300 feet in height, is wholly composed of light porous calcareous tufa. The superfluous water is carried out of this fine reservoir, by a small channel, and, wherever it rests, a deposit of tufa immediately takes place. The whole face of the country seems to be of similar formation, and even the line of mountains in the neighbourhood, some of which have an elevation of 7500 feet, appear to their very summits to be composed of the same light deposit.

Siliceous springs, or springs holding silica, or flint, in solution, are by no means of such frequent occurrence as calcareous springs. We have seen, that in order to render the latter springs highly charged with calcareous matter, the presence of carbonic acid is required, and that, as the gas becomes dissipated in the atmosphere, the deposit of the mineral substance takes place. Other conditions are necessary for the formation of siliceous springs, for it appears, that water will not hold silica in solution, unless the liquid be raised to a high temperature; siliceous springs are therefore all *hot*, or *thermal*, as well as mineral springs. As soon as the water of such springs is cooled by coming in contact with the air, the liquid, having no longer the power of holding the silica in solution, a rapid deposition occurs, and various species of rocks are formed. The most

celebrated springs of this description are those of the *Valley das Furnas*, in the Azores, and the *Geysers* of Iceland.

The former, which are in the island of *St. Michael*, rise through volcanic rocks, and form several streams, precipitating in their course vast quantities of the deposit, called *siliceous sinter*. The largest fountain, called the *Caldeira*, is nearly thirty feet in diameter, and its depth is unknown. The water of this spring is of a boiling temperature, and is in a state of constant ebullition, emitting a highly sulphureous vapour, described as smelling like burnt gunpowder. Some of these springs also hold in solution, *alumina* or *clay*, and in that case the deposits consist of a greater or less portion of that material. Such springs are called *argillaceous*. Around the circular basin of the Caldeira, the sinter accumulates, and wherever the water flows, the grass, ferns, reeds, &c., become more or less encrusted with silica; and are said to "exhibit all the successive states of petrifaction, from the soft state to a complete conversion into stone." Branches of the same ferns that now flourish in the island, are found wholly embedded in silica, preserving the same appearance as when growing, except that they have acquired an ash gray colour. Fragments of wood have also been met with; and a bed from three to four feet in depth occurs, almost entirely composed of reeds, of a species now common in the island, but which have become completely mineralized, by the deposits from this spring.

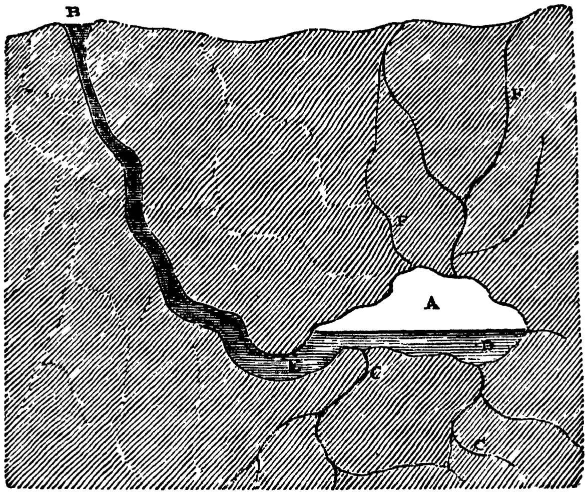
A yet more remarkable instance of the deposition of silica, or silex, is afforded by the *Geysers*, or hot springs of Iceland. The two largest of these celebrated fountains are situated in a valley near Haeckadal. The principal fountain, or *Great Geyser*, rises out of a spacious basin situated in the middle of a small eminence, or mound, formed by the deposits from the spring. The basin is of an oval form, its diameter being about fifty-six feet in one direction, and forty-six feet in the other. The depth of this basin does not exceed three feet, but in the centre is a fissure, or natural pipe, from eight to ten feet in diameter, and seventy-eight feet in perpendicular depth. The

inside of the basin is lined with a siliceous crust, which is of a whitish colour, and has a smooth surface. The mineral deposits on the outside of the basin assume a different appearance; for, owing to the splashing of the water when this remarkable fountain plays, the latter present a rough exterior, and have been compared to the heads of cauliflowers. The basin is usually filled with beautifully transparent water, in a state of ebullition. When Sir George Mackenzie visited this spot in 1810, he found the basin full of hot water, and with a small stream running out on one side by means of a channel the water had formed for itself. Sir George and his companions then proceeded to inspect some of the lesser fountains, of which there are several in the same vicinity; and on their return to the Great Geyser, they were startled by a sound like the distant discharge of artillery, and by the shaking of the ground. The subterranean noises became louder and louder, and the agitation of the earth continued to increase, until the water in the basin, after heaving several times, suddenly rose in a large column, accompanied by clouds of steam, to the height of about ten or twelve feet. The column of water then seemed to burst, and sinking down, flowed over the margin of the basin in considerable quantities. This was followed by a succession of eighteen jets, some of which rose to the height of fifty feet. After the last of these, the water disappeared from the basin, sinking within the natural pipe; and during such intermissions, the steam ceased to issue from the pipe, and all appeared tranquil. A few hours later, Sir George Mackenzie witnessed a repetition of this phenomenon, but on the latter occasion in greater magnificence, a succession of jets being thrown up, some of which attained the height of ninety feet. The accounts given by more recent travellers of this remarkable fountain correspond very closely with the description above related, though a greater height is usually assigned for the jets of water from the Great Geyser, which are said to be thrown up with loud explosions, to the height of one or two hundred feet. A column of steam is also said to rush up with amazing force, whilst a thundering noise terminates the erup-

tion. The petrifactions which are formed by the deposits from the Geysers, are very beautiful. The leaves of birch and willow are met with, converted into white stone, and in a state of the most perfect preservation, every fibre being entire. Grass, rushes, masses of peat, &c., are equally well preserved; and in some cases, the plants encrusted with sinter, present a very similar appearance to those encrusted with calcareous tufa at Knaresborough. Amongst other products of the Geysers is tripoli*, whilst the circular reservoirs into which these fountains fall, are filled with a variety of opal.

Various hypotheses have been suggested, to account for the phenomena presented by these remarkable fountains. One of the most satisfactory is that proposed by Sir George Mackenzie, and which will be better understood by a reference to the accompanying diagram. Water percolating through the rocks on the surface of the earth, may be supposed, by means of the fissure, F F, to penetrate into the subterranean cavity A; whilst at the same time, steam, at a very high temperature, being thrown up from the internal source of heat, emanates from the lower fissures C C. The heat produced by this jet of steam, causes the water in the cavity to boil furiously; and when this has been continued for a sufficient length of time, the upper part of the cavity becomes filled with steam. Confined within that limited space, the steam is under what is termed *high pressure*, that is, there is no outlet by which it can escape, and owing to its elasticity and expansive power, it presses with great force in every direction; and were there no outlet for the water, the probable consequence would be a violent disruption of the rocks

* The researches of Professor Ehrenberg have disclosed the fact, that the tripoli of Bilin in Bohemia consists almost entirely of siliceous shields of fossil infusoria, apparently deposited in successive layers. It would be an interesting point to ascertain whether the tripoli of Iceland be of similar formation; for if indeed, like the former, the silex it contains consists of the coverings of infusoria, it may lead us to suppose that these minute creatures are not only adapted for existing in water at a high temperature, but that probably they may actually require it for their development. An additional proof would thus be afforded that every condition of things on the earth's surface is suited to afford sustenance to living creatures.



Geyser.

in all directions. But the fissure or crevice E B, forms a safety pipe, and by the power of the steam, the boiling water is forced up this pipe, and thrown out on the earth's surface to a greater or less height, according to circumstances. In the meanwhile, though the water at D becomes diminished in volume, yet the steam, which before was compressed within a small space, now gives proof of its elasticity by expanding, and continuing to expand, until the whole of the water in the cavity is driven into the pipe; the steam then itself rushes up the pipe with great force and velocity, and with a thundering noise; forming, as we have already seen, the termination of this remarkable natural exhibition. If stones are thrown from above into the pipe, and this safety vent thus closed, the water is made to boil more violently, and should the force of the steam not drive the stones upwards, and thus cause an eruption, an explosion would take place, and the rocks themselves be shivered to pieces. Mr. Henderson made the dangerous experiment of throwing a considerable number of large stones down the pipe

of the Strokr, one of the Geysers, and found that he could by this means, bring on an eruption in a few minutes. The fragments of stone were cast up with the boiling water, the latter being thrown up to a much greater height than usual. After the whole of the water had been ejected, a column of steam continued to rush up with a deafening roar for nearly an hour. But the Geyser, as if exhausted by this unwonted effort, did not recommence its eruptions after its ordinary interval of repose had elapsed.

Bituminous or *petroleum springs*, that is, springs impregnated with petroleum and the various minerals allied to it, such as bitumen, naphtha, asphaltum, and mineral pitch, are very numerous, and are in many cases evidently connected with subterranean heat, occurring either in the vicinity of active volcanos, or in districts where traces of igneous action are distinctly observable. Springs of this description are met with in some of the districts bordering on the Caspian Sea; they also are very numerous in the tract of country constituting the ancient Mesopotamia. The greater part of these regions present indications of volcanic action; but that these springs are not confined to such localities, appears from the following circumstance. In an Artesian well recently formed in the department of the Bas Rhin, a jet of water has been obtained, copiously charged with the best petroleum. This mineral substance was so abundant in this fountain, that it has been collected, and applied with great advantage to economical purposes.

CHAPTER XIV.

THERMAL SPRINGS.

Much difference is observable in the temperature of springs: some being very hot, and others comparatively cold; whilst almost every shade of temperature occurs between those two

extreme points. It might therefore appear difficult to decide at what point to draw the line between hot and cold springs; where the one should commence, and the other terminate. Dr. Daubeny has proposed, and this will doubtless be found a very convenient mode of determining the point, that springs should rank as *cold* when their temperature is the same, or nearly the same, (that is, but little above) the mean, or average temperature of the locality where they occur; but when of a more elevated temperature, they may be considered as *thermal*, or *hot* springs.

According to the above mode of distinguishing thermal from cold springs, however, a spring issuing from the ground at a moderate temperature, may form a thermal spring in one country, whilst it would be a cold spring in another. Thus, the mean temperature of this country being, according to Dr. Daubeny, estimated at 49° Fahrenheit, the mineral spring at Bakewell in Derbyshire, the temperature of which is 62°, is a thermal spring, coming to the surface as it does in Britain; but if another of precisely similar temperature were to issue forth in Southern Italy, or Sicily, where the mean temperature is assumed to be 63°, it would constitute a cold spring in that region.

Nor do these remarks apply to land or superficial springs, but to those only which issue from considerable depths. Land springs, deriving their supplies directly from the atmosphere, are liable to vary in temperature with that of the seasons, and of the rain by which they are supplied. The heat of the sun also penetrates to a certain depth in the earth, and springs having their source within the limits of that range, are liable to variations in their temperature. Beyond that particular depth, however, the solar influence and the consequent fluctuations of temperature wholly cease, and a constant or unvarying temperature is maintained. Thus, it has been found, from observations made in the vaults beneath the Observatory at Paris, which are situated at the depth of 87 feet below the surface of the ground, that the temperature has not varied for more than half a century. The depth of this line of uniform temperature

is not the same in all localities, for, owing to the different nature of the strata at the earth's surface, and their consequent different conducting power, the solar heat penetrates to a greater depth in some places than in others; it appears, however, nowhere to exceed 100 feet; and the temperature at this line, as far as observation has been carried, is found generally to correspond very nearly with the mean annual temperature of the surface. Springs deriving their supplies from reservoirs at this depth, might therefore be expected to possess a temperature similar to the mean temperature at the surface; and would accordingly, in the strictest sense of the term, (as defined by Dr. Daubeny,) constitute cold springs. And indeed, when no local disturbance occurs, to affect the temperature of the strata from whence the spring may issue, such is found to be the case. And yet further, springs having their origin from reservoirs situated in this line or zone of uniform temperature, are likely to be the coldest of any that issue from the earth, excepting perhaps only, such as derive their supplies directly from snow water: for it appears that beyond this zone, an increase of temperature is observed to take place, on descending deeper into the interior of the earth. The amount of this augmentation of temperature varies in different localities, owing to the different nature of the rocks, and other circumstances, but is considered to be, on an average, about one degree of Fahrenheit in forty-five feet. Such being the case with the solid contents of the globe, we shall be led to expect that the latter will communicate their higher temperature, to the bodies of water treasured up in their cavities; a conclusion which is borne out by facts; for, from observations made during the construction of Artesian wells, it appears, that the temperature of water, derived from sources below the line of uniform temperature, augments with the depth, and that the ratio of this increase nearly corresponds with that observed to take place in the rocks which form the earth's crust, being like that also subject to some variations, dependent on local circumstances, and attributable to similar causes. These trifling variations do not, however, affect the general principle, and it may be considered as an ascertained

fact, that as we descend into the earth, an increase of temperature takes place, both in solid rocks and in accumulations of water, in proportion to the depth below the line of uniform temperature. This circumstance is attributable to the internal heat of the globe, which increases towards the centre, and, were it not for the external heat derived from the sun, the very surface would be the coldest, but as the earth is at present constituted, this is determined by the depth to which the solar heat penetrates, and the zone of greatest cold consists in fact of that particular line, to which no solar heat extends, and which, from its distance from the centre, possesses the smallest portion of terrestrial heat.

But although some thermal springs evidently owe their higher temperature to the internal heat of the globe, this is by no means the sole cause of the elevated temperature of all hot springs, for it appears that the heat of most thermal waters which possess a very high temperature, is in great measure attributable to the various igneous disturbances in the earth's crust, either as at present exhibited in active volcanos, or in the more ancient commotions, caused by subterranean fire, similar in character to that at present exhibited in the phenomena of volcanos and earthquakes. The latter description of internal heat, it will be observed, differs totally from that before mentioned. The internal heat, which gradually increases as we approach the centre of the earth, is quiet in its operations, and though perhaps essential to the maintenance of the terrestrial globe in its present condition, exhibits no signs by which its presence can be detected; nay, its very existence might have remained unknown, had not the most careful investigations and patient observations led to this conclusion. The phenomena of volcanos and earthquakes, on the other hand, make themselves heard, and these, instead of being, like the former, of universal occurrence in all parts of the globe, are limited to certain areas, and in some of these, again, the igneous action appears so far to have spent itself, that it displays no external evidence of the effects of subterranean fire, though beneath the surface, considerable heat is still retained; whilst in others, the

energetic action of intense heat is shown, by the molten minerals which are poured forth by volcanos. These two latter conditions of the earth's crust, give rise to the greater number of thermal, or hot springs. It further appears from the observations of M. Brongniart, that the hottest springs are those associated with recent volcanos; the next in order, are such as proceed from strata presenting evidence of igneous action, though now externally extinct; whilst the lowest on the scale are such as are connected with aqueous formations, and appear to derive their greater or less degree of temperature, solely from the natural internal heat of the globe.

Among springs remarkable for their high temperature, and having their origin in the vicinity of active volcanos, few are more deserving of attention than the *Geysers* of Iceland, which are not less distinguished for the grand exhibition of their intermittent fountains, and their interesting deposits of silica, than for their very high temperature. According to recent observations made by M. Lottin, the temperature of the water of the *Great Geyser*, at the depth of about eighty feet, was found to be 257° Fahrenheit, or 45° above the boiling point; and that of the *Small Geyser*, at the depth of about fifty feet, was 232°. Water in a small hole at the surface of the ground, was met with, having the temperature of 214°. To the same class belong also the springs in the volcanic island of *St. Michael's*, to which allusion has likewise already been made, in speaking of siliceous springs, and which are equally remarkable for their high temperature. All the springs in the island of St. Michael's do not, however, possess this elevated temperature, some being moderately warm, and others quite cold. The hot springs, nevertheless, are the most numerous, and, besides those already mentioned for their remarkable deposit of sinter, several other smaller boiling springs occur, and vapour, or steam, is seen issuing from the crevices of the rocks in many places. By applying the ear to some of the latter, the noise of boiling water may be distinctly heard, whilst from others, boiling water is thrown out at intervals, scalding those who may incautiously or unwarily approach too near. Fuel is a very

scarce and expensive article in this island, and the peasants consequently take advantage of these boiling waters, cooking their victuals by means of this natural steam apparatus, and placing their culinary utensils, either over the boiling springs, or resting them upon some of the crevices from whence steam issues.

Among springs connected with extinct volcanos, are those of *Hungary*, the *mineral springs of the Rhine Provinces*, the *thermal springs of Central France*, especially those of *Mont D'Or*, where the very baths exist, which were constructed in the time of Julius Cæsar. The thermal springs of Asia Minor may also be included in this class. Such are those mentioned by Mr. Hamilton as occurring near *Singerli*, the waters of which, at a mile from their source, are still of sufficiently high temperature to form a hot bath; and those of *Capliza*, near the city of Prusa, which are so hot, that they require to be mixed with cold water before they are fit for use. The remains of ancient baths occur at Capliza, supposed to be those described by ancient authors as the "Royal hot waters," which it appears were used by the Greeks during the flourishing times of the Empire. New baths have been constructed in this locality; and so high is the temperature of these springs, that the hand cannot be held in the water; whilst eggs immersed in it, become soft boiled in ten or twelve minutes, and completely hard in less than twenty minutes. It has a strong sulphureous smell.

Another class of thermal springs are those situated in the vicinity of uplifted mountain ranges. To give rise to a disturbance in the earth's crust of sufficient amount to cause the uplifting of a whole mountain ridge, we cannot but conclude that some mighty agent has been at work, some energetic display of subterranean fire. In the evidence thus presented of igneous action of intense amount, though displayed at some antecedent period, we find the cause of the high temperature of springs issuing from such localities; for, although no longer exhibited externally, sufficient heat may be retained internally, to raise the temperature of the stores of water treasured up among these rocks. In the neighbourhood of uplifted mountain ranges,

thermal springs often occur in groups, or are met with in a line at the foot of the mountain ridge. Thus, there is a group of thermal springs manifesting itself at the base of the central range of the Alps, as at *Baden* in Argau, *Schinnach*, *Pfeffers*, &c.; and also on the western flank of the same mountain range. In European Turkey, again, a line of hot springs occurs to the south of the mountain ranges of *Balkan* and *Orbelus*, extending from east to west, the highest temperature of the springs in this locality being 162° Fahrenheit. The thermal springs of the *Pyrenees* belong to the same class; and Professor Forbes, who visited this spot in 1835, has shown that these thermal springs for the most part gush out from the vicinity of *intrusive* rocks, that is, of igneous rocks, such as granite, serpentine, &c., which have intruded, or forced their way into the stratified rocks; and he has observed that several of these thermal waters rise exactly from the point of junction of the granite with the stratified rocks. Such is the case with the hot spring of *Bagnere de Luchon*, and the very abundant spring of *L'Escaldas*, both of which rise from granite, near its junction with slate.

Thermal springs, which are contiguous to extensive faults, or dislocations, approach very near in character to those just described, and owe their high temperature to similar causes. The celebrated *Carlsbad* waters afford an example of this description of spring. This copious spring issues from a narrow glen, presenting the indication of some great natural convulsion. The temperature of the Carlsbad waters is about 167°. Striking instances of the connection between dislocation in the strata, and the bursting out of thermal springs, are exhibited in our own country, both at *Matlock*, and at *St. Vincent's Rocks* near *Bristol.*

The hottest spring in Great Britain, is that called the *King's Well*, at *Bath*, its temperature being 115°, or about 66° above the mean temperature of our island. The product of this spring is 28,339 cubic feet of water daily. *St. Anne's Spring* at *Buxton*, which is next in temperature to the springs at Bath, does not exceed 82°, and the hot well at Bristol has only a temperature of 74°.

The hottest spring in Europe, exclusive of the Geysers, or any of those affected by volcanos at present in a state of activity, appears to be that of *Chaudes Aigues*, near Aurillac in the Department de Cantal; the temperature of this spring, which yields daily 307,188 cubic feet of water, being 174°.

We have seen that in the island of St. Michael's hot and cold springs are met with at very short distances from each other; this is by no means an uncommon occurrence. Thus, Sir James Alexander mentions that in *Southern Africa*, hot and cold springs situated very near together, issue from the ground at the foot of a ridge of hills. The latter instance is rendered more remarkable by the circumstance, that nearly contiguous hot and cold springs issue on both sides of the ridge, on the one side uniting their waters, and forming a lake several miles in extent; and on the other, losing themselves in a richly verdant plain, which doubtless owes its fertility to this natural underground irrigation. In the *Pyrenees*, again, Professor Forbes met with hot and cold springs issuing forth, within a few yards of each other. In such instances, we may well conclude, that the sources of the springs are separated from each other by a line of fault, and that the one derives its supplies from atmospheric moisture, accumulated in some reservoirs near the surface, whilst the other rises from a much greater depth, where the stores of water have become heated, either by the proximity of igneous rocks still retaining a high temperature, or simply by the natural internal heat of the globe at greater depths.

Springs which occur in volcanic regions are subject to vary in their temperature, with the greater or less degree of igneous action, which may at any particular period be developed in such localities. Thus, by means of the convulsions attendant on the formation of *Jorullo*, in Mexico, and the igneous action which gave rise to that remarkable phenomenon, two small streams of *cold* water disappeared, or were swallowed up, but re-appeared on the opposite side of the volcano, as one *thermal* spring. Since the period of that mighty convulsion, no indica-

tions of renewed igneous action have occurred; the volcano has ceased to emit smoke, and the whole region has appeared to be undisturbed by subterranean fire; and with this apparent diminution in the temperature of the rocks, the waters of the newly-formed thermal spring have also gradually cooled down. On the other hand, the temperature of the spring of *Las Trincheras, in Venezuela* has been augmented since it was observed by De Humboldt in the year 1800. At that period, the waters of this spring possessed a temperature of 195° Fahrenheit; but in 1823 this had increased to 206°. According to De Humboldt this spring is not connected with any active volcano; but, that this augmentation of temperature was due to intense subterranean heat, appears evident from the circumstance that in the intermediate period between these two observations, the severe earthquake had occurred which, in the year 1812, destroyed Caraccas, and extended over all Venezuela, which even visited the island of St. Vincent, and convulsed the valley of the Mississippi for the distance of three hundred miles. In this latter instance, although the increase of heat in these waters is undoubtedly like that of the newly-formed thermal spring at Jorulla, attributable to igneous action, we must, in the case of the spring of Las Trincheras, seek for this at a far greater depth below the surface; and therefore there may be reason to expect, that the latter spring will not experience the same sensible diminution of temperature, within so short a period as has been observed in Jorullo. This is a point which, however, only time and future observations can decide.

Thermal springs, which are not immediately connected with active volcanos, or with violent convulsions of the earth, are not subject to an increase or diminution of temperature, but appear to undergo no sensible change for long periods of years. *Exact* observations for any great length of time of course cannot be obtained, but it has been found that the mineral spring at Carlsbad, possessed in 1822, the identical temperature which belonged to it in 1770; so that no change whatever had occurred in more than fifty years. And with regard to less

precise observations as to the permanent temperature of springs, many circumstances lead to the conclusion that very little, if any variation, can have taken place in several of the most celebrated thermal springs, many of them which are at present resorted to for their restorative virtues, having been employed in a similar manner 2000 years ago. That the thermal springs at Bath were not unknown to our Saxon ancestors, is clearly indicated by the name this city still retains, *bad* being the Saxon word for bath. That this spot was also frequented by the Romans for its thermal waters, is proved by the remains of baths which have been met with in that place. Thus, when the Abbey House was pulled down in the year 1755, the remains of baths, seemingly on a grand scale, were discovered beneath the foundations of that edifice. The floors of these baths were raised on square pillars of brick, whilst tubulated or hollow bricks were laid round them, designed, as has been supposed, to convey the water to the bath, though perhaps in some instances also adapted for fulfilling the further purpose of maintaining the temperature of the water in the baths, by means of continued supplies of hot water fresh from the spring. We may therefore conclude that the temperature of the Bath mineral waters must, at the time when the Romans held possession of this portion of our island, have very nearly, if not entirely, approached to that still maintained by them in the present day. Other instances of permanency in the temperature of thermal springs might be adduced, but this, with those already incidentally cited, in speaking of mineral springs at Caliza, and on Mont D'Or, will suffice for our present purpose.

We have seen that springs generally appear to derive their supplies of water from atmospheric moisture, which percolates through porous strata, or finds its way into the earth through crevices and fissures; and which, when an outlet is obtained, again issues to the surface on the principle of hydrostatic pressure. Springs which are thus supplied, however, cannot but be liable to be more or less affected by the weather, and after long continued droughts, it will be evident that they will be

subject to become languid, if not altogether to fail. The less deep the source of the spring, and the less extensive the reservoir, the more likely will this be to occur; and we well know that it is by no means an uncommon event for land or superficial springs to fail during the dry weather of summer. In the greater number of thermal springs, however, the volume, or quantity of water, does not appear to be subject to such variations; a circumstance which has led to the supposition, that they are not wholly dependent on the atmosphere for their supplies of moisture. The question therefore naturally presents itself, from whence, then, can their supplies of water be obtained? Mr. Lyell has suggested, as a probable solution of this question, that it is by no means impossible that the bed of the ocean, may, like the dry land, possess permeable, as well as impermeable rocks, and that through these, as also by means of fissures and crevices, large quantities of salt water may find its way beneath the floor of the ocean, into the interior of the earth. The difficulty, however, appears thus to be only half overcome; for, though water entering in this manner into the earth, might, and if it encountered impervious rocks, or a fault, to impede its onward progress, would, in accordance with the laws of hydrostatics, if it met with an outlet, find its level so far, as to ascend nearly to the height of the surface of the mighty reservoir from whence it proceeded; yet this could never account for its appearance *above* that level. Whereas, in fact, the greater number of these never-failing thermal springs, issue from the ground at an elevation considerably above the level of the ocean. The hot springs at Bath and Bristol, it is true, are nearly on a level with the ocean, but that at Buxton is 400 feet above that line; the Carlsbad spring, 1100 feet; the hot spring on Mont d'Or, 3400 feet; and some thermal springs have an elevation of more than 10,000 feet above the sea-level. To account for these springs being raised to so great an elevation, Mr. Lyell supposes, that the water which has thus found its way into the interior of the earth, there encounters, especially in the volcanic regions, a heat of sufficient intensity to convert it into

steam, or vapour*. In this state, it rises upwards, and as it approaches the surface of the earth, where the temperature of the rocks is lower, it becomes condensed and re-converted into water, and accumulates in the internal reservoirs, which form the sources of thermal springs; and these latter, being thus supplied, are never subject to fail, so long as the internal arrangements continue undisturbed. The temperature of such springs will of course be dependent in great measure on local circumstances, such as the conducting and consequently cooling nature of the rocks in which the reservoirs may be situated; the distance the subterranean stream may traverse ere it finds an outlet; or again, the supplies of atmospheric moisture which may mingle with the hot water, and thus lower its temperature before it makes its appearance at the surface, in the form of a spring. To return, however, to Mr. Lyell: "It would follow," observes that eminent geologist, "from the views above explained, that there must be a two-fold circulation of terrestrial waters: one caused by solar heat, and the other by the heat generated within the interior of our planet. We know that the land would be unfit for vegetation if deprived of the waters raised into the atmosphere by the sun; but it is also true, that mineral springs are powerful instruments in rendering the surface subservient to the support of animal and vegetable life. Their heat is said to promote the development of the aquatic tribes in many parts of the ocean, and the substances which they carry up from the bowels of the earth, to the habitable surface, are of a nature, and in a form which adapts them for the nutrition of animals and plants."

* Dr. Daubeny has suggested that this effect may be produced by chemical processes carried on in the interior of the earth. The various substances with which thermal waters are usually charged, gives much colour to this supposition; for did they wholly originate in condensed steam, we might expect them to be the purest springs issuing from the ground, whereas thermal springs almost invariably contain a more than ordinary proportion of mineral ingredients. Probably both these agents may unite in accomplishing this end; nor is it impossible that voltaic electricity may also lend its powerful aid.

Thus do we find, that every fresh investigation of the various conditions and phenomena of the natural world, teems with additional proofs of a Superintending Providence, overruling all things to the benefit of the organized inhabitants of the globe. And whilst it forms one of the noblest exercises of the human intellect to trace these phenomena from their effects to their causes, to investigate the laws by which the universe, nay every individual particle of it, is governed, to mark the evident signs of Wisdom, Power, and Goodness, both in the creation and the maintenance of the whole fabric: such researches are not less remarkable for their practical utility; for almost every advance in knowledge brings to light properties of matter hitherto undiscovered, or leads to new and useful applications of those with which we may be acquainted. To observe and take advantage, for beneficial purposes, of the qualities imparted to any substance by the Creator, cannot be otherwise than a fitting occupation for a creature endowed with perceptive and reasoning powers; whilst the consideration that "Nature performs nothing in vain," may instil into our minds the practical lesson of endeavouring to follow in her footsteps, and, as far as is permitted us, to turn everything to profitable account.

As a simple illustration of the above remarks, let us briefly consider some of the various applications of thermal waters to economical purposes. The thermal waters which have thus been made use of, on account of their elevated temperature, are chiefly such as have been obtained by means of Artesian wells, though in some instances other thermal springs have been similarly applied.

At a manufactory in Wirtemberg, M. Bruckmann, by means of water issuing from several Artesian wells, possessing a temperature of 54°, and caused to flow through pipes surrounding the building, has succeeded in keeping up the temperature of several workshops to 47° Fahrenheit, in the depth of winter, whilst the thermometer in the external air was at zero, or 32° below the freezing point. The waters of the natural thermal spring of Chaudes Aigues, at Aurillac,

(already alluded to as the hottest known spring in Europe,) have also long been applied to similar purposes. In other places, greenhouses and conservatories have been maintained at a nearly equable temperature throughout the whole year, by means of large bodies of water, of Artesian origin, encircling the buildings. Whilst contemplating these actual applications of thermal waters to such purposes, and learning what has been effected by such means, we almost cease to smile at the erst apparently utterly absurd account given by an old writer, of volcanos and hot springs in Greenland, which served to warm the houses, cook the victuals, and make the fruits of the South thrive, in North latitude 74°!

Another economical purpose to which the warmer water derived from Artesian wells has been applied, is the preservation of fish in ponds. It has often been found, especially in countries where the climate is more *excessive*, or subject to greater extremes of heat and cold than is that of Great Britain, that the fish in ponds are liable to perish in winter from the low temperature of the water, and in summer from its high temperature. By supplying such ponds with water from an Artesian well, the extreme change of temperature in the water may be prevented, and the excess of heat and cold avoided. The experiment is said to have completely succeeded in a fish pond at Montmorenci.

Another application which has been made of water possessing an elevated temperature, and derived from Artesian wells, has been to maintain the action of hydraulic wheels in severe weather. The duration of frost in our island is rarely of sufficient length to render this an object of importance with us; but in regions where the rivers are ordinarily frozen over for two or three months, the cessation from work may often be attended with much inconvenience.

> When the stream
> Is mute, or faintly gurgles far below
> Its frozen ceiling; silent stands the mill,
> The wheel immoveable, and shod with ice.

To remedy this evil, water of elevated temperature, derived

from Artesian wells, has been conveyed into the stream in which the mill-wheel is situated; where it is employed either to prevent the accumulation of ice, or to dissolve the flakes which may have been formed, and which would impede the motion of the wheel. Or, in some instances, where it can be obtained in sufficient abundance, the warmer water may itself be used as a motive power for turning the machinery; and, owing to the equable as well as elevated temperature of water proceeding from great depths, the motion of the wheel may by such means be continued during the severest winters.

The application of the warm waters of Artesian wells for dissolving ice, finds a near parallel in nature, among the snow-clad heights of the Himalaya Mountains; where, remarkable as it may at first sight appear, thermal springs of very high temperature are met with. The particular instance to which we at present allude, is a hot spring mentioned by Captain Hodgson, as occurring at Jumnotri, near the source of the river Jumna, at the elevation of 10,849 feet above the level of the sea. The Jumna, which at this place only consists of a small stream, was, at the time of Captain Hodgson's visit, arched over by vast masses of frozen snow, extending about 180 feet in width, and having a thickness of about 40 feet. These masses were very solid and hard frozen, forming arches over the stream, resembling vaulted roofs of marble. The thermal spring was situated on the borders of the little river, and the steam arising from the hot water, melted the under part of the glacial arches, causing the water to fall from thence in showers, like heavy rain, into the stream beneath, which seemingly owes its origin in great measure to the supplies it thus receives. Captain Hodgson found that this spring had a temperature of 194° Fahrenheit, which at the great elevation where it occurs, approaches very nearly to the boiling-point of water. Nor does this form a solitary instance of thermal springs occurring in these elevated regions. Captain Johnson, who visited this locality at a more recent period, observed another thermal spring not far from that mentioned by Captain Hodgson, which

possessed a sufficiently high temperature to boil rice. Thermal springs, indeed, appear to be of such frequent occurrence in this part of the Himalayas, that Captain Johnson met with them almost daily in his route among these mountains. To return, however, to our more immediate subject. "The existence of hot springs amidst the icy coverings of the Himalayas," observes Captain Hodgson, "points out a beautiful provision of nature for the supply of water to the rivers in the winter season, when the sun must have little or no power to melt the snow in these deep and narrow defiles." And thus do we find these thermal waters naturally performing a nearly similar office with that to which, as we have just seen, the warm waters derived from deep Artesian wells have been applied,—the maintenance of a flowing stream of water amidst frost, and ice, and snow. There is certainly no reason to suppose that, in this particular instance, the natural has given rise to the artificial application of thermal waters to these purposes; but the consideration that such things are affected by natural means, cannot but lead us to the reflection that many highly useful hints may be acquired, from a careful observation and imitation of the operations carried on in the natural world.

We cannot close this brief notice of thermal waters, without adverting to another use to which they have been applied, and which, though infinitely less important than any of the preceding instances, may nevertheless not be without interest to some of our readers, namely, their application to the revival of drooping flowers. The fact that this effect will be produced by thermal waters appears to have been long known to those who reside in the vicinity of hot springs, who have remarked that decayed flowers plunged into the waters of the spring become fresh and beautiful. Of course there must be a limit in their decay, beyond which the restorative power of hot water will not extend; but it has been found that if flowers which have been twenty-four hours out of water, and which appear quite dead, are plunged into hot water, as the water gradually cools, the flowers revive and recover their fresh appearance. This is

an experiment which may with the greatest facility be made; and how often may it not be gratifying thus to call, as it were, into re-existence, choice or favourite blossoms carried perhaps from a distant spot; and which, without this simple means of restoration, would present only a sad and withered spectacle.

CHAPTER XV.

RIVERS.—UPPER COURSE OF A RIVER.—CATARACTS AND RAPIDS.

Rivers form a principal feature on the surface of the globe. Not only do they enrich and beautify the territories through which their course extends, but they also fulfil a very important and beneficial office in the economy of nature, by carrying off to the ocean, the greater portion of the redundant waters from the face of the earth, these being, in most cases, drained into the lowest part of the ravine, or basin, which constitutes the bed of a river. They also are, in many points of view, of direct utility to man; yielding, as the larger number of them do, abundant supplies of good and wholesome water, and affording an ample provision of grateful food, in the fish they contain. Nor is this all; for they also form, in many instances, highly useful agents for propelling machinery, and are of great importance as navigable channels. Rivers likewise perform a part of much importance in the changes effected by their means in the crust of the earth, both by their destroying and transporting power, and by their renovating effects; the latter being shown in the deposits of fluviatile mud which they leave in their course, and the deltas which many of them form at their mouths, thus imparting richness and fertility to the champaign districts which they traverse.

"He who looks with a careless eye at a map of the world, is apt to consider the rivers which are dispersed over its surface, as a chance medley of the channels which carry off the waters. But it will afford a most gratifying subject of consideration, to

direct our attention to the mode in which the surface of the earth is drained of its superfluous waters. In following the troubled waters of a mountain torrent, or the more peaceful streams which spring from less elevated sources, until we see them swallowed up in the ocean, we shall be delighted with observing how the simple laws of mechanics, are made so fruitful in good consequences, both by modifying the motions of the waters themselves, and also by leading to new conditions on the surface of the earth, sometimes being themselves instrumental in producing the very modifications of their motions which render them so beneficial. The permanent beds of rivers are by no means fortuitous gutters, which have been scooped out by dashing torrents; but both they, and the valleys through which they flow, are the patient, but unceasing labours of Nature, prompted by goodness, and directed by wisdom*."

The laws of mechanics, which are thus "made so fruitful in good consequences," have already engaged some of our attention, in speaking of the phenomena of flowing water; and it now only remains for us to accompany rivers in their progress across the surface of the earth:

> From the rude mountain and the mossy wild,
> Tumbling through rocks abrupt; * * *
> Thence o'er the sanded valley spreading far,
> Calm, sluggish, silent.

When we trace rivers to their *sources*, we find that, with very few exceptions, all have small beginnings. Indeed, it is sometimes by no means an easy task to decide which of two or three little brooks, possesses the best claim to be regarded as the main or leading stream; for, in comparatively flat districts, it often happens that in the early part of its course, each feeder of a river consists only of a small rill, which would not ramble far from its source among growing plants and permeable strata, without being either absorbed, or else carried off by evaporation, did it not unite its waters with those of other rills. When two such little rills are united, though perhaps they form an inconsiderable body of water, yet the stream is far more able by its increased volume, to overcome any obstacle to its pro-

* *Encyclopædia Britannica*, art. Rivers.

gress; and the motion of the water being, as we have before seen, accelerated by increase of volume, the rivulet, (provided other conditions be similar,) moves with greater velocity than the separate rills would have done. And we need scarcely again call the reader's attention to another no less important result from the admirable arrangements, also before alluded to, in the natural world:—namely, that since two streams of equal size, have, when united, usually little more than the same extent of surface as that possessed by each separately, the absorption and evaporation of the water flowing downwards, will therefore be diminished by the union of two or more rills; and thus, the portion of water which travels towards the ocean, is continually increasing in greater proportion than the increase of the whole volume of water. And hence we find, by this happy adjustment, that not only do the waters occupy less space as they advance, but by their augmented power, they are enabled to scoop out for themselves deeper channels, by which means, instead of spreading over a larger extent of country, the waters are collected into comparatively contracted beds, forming deep and navigable rivers.

In the immediate vicinity of the sea, however, different conditions usually prevail; because, in such situations, the velocity of the stream is checked by the opposing flood-tides of the ocean. Nevertheless, as the whole of the waters pouring down the river, must still be discharged into the ocean, tidal rivers require a larger bed the nearer they approach to their final termination, and this enlargement of the beds of rivers near their embouchure, usually consists in the widening, rather than the deepening of the channel. Where the force of the stream, and that of the flux of the sea, are well balanced, little change is observed to occur at the mouths of rivers. When the stream has not sufficient force, the opposing tides sometimes drive the sand into the channel of the river, so as to form bars, or sand-banks, at their mouths; and since, under such circumstances, owing to the decrease in the volume of water, the velocity of the stream will be diminished, a considerable deposition of mud and silt usually takes place. When rivers discharge themselves into lakes, or into tideless, or nearly

tideless seas, such as the Mediterranean Sea and the Gulf of Mexico, the silt and mud borne down by the waters, are deposited at the entrance of the rivers, forming additions to the land, usually termed *deltas*. Of this description are the dèltas of the Nile, and of the Mississippi. In the open sea, also, whenever the volume of water carried down by a stream is so great as to counteract, and almost neutralize the force of tides and currents, so that the latter have not power to bear away and remove to a distance the whole of the sedimentary matter periodically brought down by the river, deltas are produced. These depositions at the mouths of rivers sometimes increase with considerable rapidity; of which the accession of land at the mouth of the river Po, forms a striking example; Adria, which was a seaport in the time of the Emperor Augustus, being now about twenty Italian miles inland*. Ravenna, also a seaport, and which at the same period formed a naval arsenal of considerable importance, is now some miles from the main sea, whilst the remains of the ancient city have been wholly entombed by the deposits of sand and mud, and are now several feet below the surface.

The tract of country which is drained by a river is termed a *basin*, an appellation derived from the form of the ground, which rises with greater or less steepness on three sides, in some measure resembling the shape of a basin, or, perhaps, more nearly that of a trough, in the hollow or lowest part of which the river runs, collecting and carrying off the superfluous waters from the whole area. The ridge of elevated land which forms the margin of such a basin, usually at the same time, also constitutes the margin of a contiguous basin, thus forming the boundary line between two valleys, or basins. From this elevated margin the waters descend on each side towards the respective basins, and hence the line of this ridge has been termed the *water-shed*.

The *sources*, or first waters, of rivers are usually derived from springs. These, as we have seen, sometimes, though

* An Italian mile contains 1766 yards; and is therefore very similar to an English mile.

rarely, issue from the earth near the summits of mountains; sometimes in low and level situations, where, since there is not sufficient slope to allow them to run freely off, the waters accumulate and form either marshes and swamps, or else lakes and ponds; and sometimes, and in fact far more frequently, at the foot of a declivity, or on the sides of hills and mountains. When a spring issues in a sloping ravine or valley, the portion of such a valley situated above the point of issue, is termed the *combe;* and we find that many of our towns have derived their terminations from this appellation: indeed, there can be little doubt that the existence of a copious spring of good water, may, in the first instance, have led to the erection of human dwellings on the particular spot, and that by degrees these grew into towns and villages. Thus we meet with Ilfracombe, Farncombe, Addiscombe, &c.

In some few instances, springs issue from the ground in sufficient volume to form rivers at their first commencement. Thus, the Sorgue (before alluded to, in speaking of springs,) rises at once from the ground in the form of an actual river; and Burchell mentions that the small but beautiful river Krumen, in Southern Africa, rises out of the ground in a full stream. It is, however, not a little remarkable, that the latter precocious river, instead of possessing the character of an ordinary stream, and increasing in its progress as it flows onwards to the ocean, absolutely reverses the usual order of things, and is smaller in its end than at its beginning, being gradually lost by evaporation, and absorption in the sands.

The generality of springs are, however, of smaller size, and their waters pour forth in the form of *rills*.

> Go up and watch the new-born rill
> Just trickling from its mossy bed,
> Streaking the heath-clad hill
> With a bright emerald thread.
>
> Canst thou her bold career foretell,
> What rocks she shall o'er-leap or rend,
> How far in ocean's swell
> Her freshening billows send?

Rills, or *brooks*, may be considered as the smallest description of rivers. When such a river has its source near the sea, or near a large river or a lake, and finds its termination in any of these bodies of water, after only a short course, it drains a very small surface, and its basin is very limited. Instances nevertheless do occur, of rivers taking their rise at a short distance from the sea, and yet forming streams of considerable magnitude. Thus the broad and rapid river Yokulsa, in Iceland, has a course scarcely three miles in length from its source to the ocean. This river, however, has its origin in the vast glaciers of Klopa Yokul; and, therefore, cannot be regarded as belonging to the class of rivers having small beginnings and so included among rills and brooks.

When two brooks unite their waters, the stream is called a *rivulet*. The basin of a rivulet is more complicated than that of a brook, for it is considered as extending to the source of all the *feeders*, or springs, which may be situated at greater or less distances on the sides of the main, or leading basin. When several rivulets unite, and thus form a considerable volume of running water, the water-course constitutes a *river*.

Not only, however, do brooks and rivulets unite to form a river, but it further very commonly happens, that before a stream enters the ocean a junction takes place between two or more rivers, and thus a large river is produced. When such an arrangement occurs, it forms a *system of rivers*. In the latter case, the basin becomes far more extended, and frequently a vast surface of country is drained by the whole water-course. The area drained by the river Thames is estimated at about 5000 square miles. This, though extensive when compared with the basins of many of our smaller streams, sinks into utter insignificance, when placed in comparison with those of some of the great rivers of the globe. The following table exhibits the estimated extent of a few of the most remarkable river-basins on the earth's surface:—

River-Basins.	Square Miles.
Thames	5,000
Rhine	89,000

River-Basins.	Square Miles.
Euphrates, including the Tigris	243,000
Danube	312,000
Indus	410,000
Ganges	443,000
Volga	653,000
Nile	707,000
Yang-tse-Kiang	742,000
Mississippi	1,100,000
La Plata	1,560,000
Amazonas	1,920,000

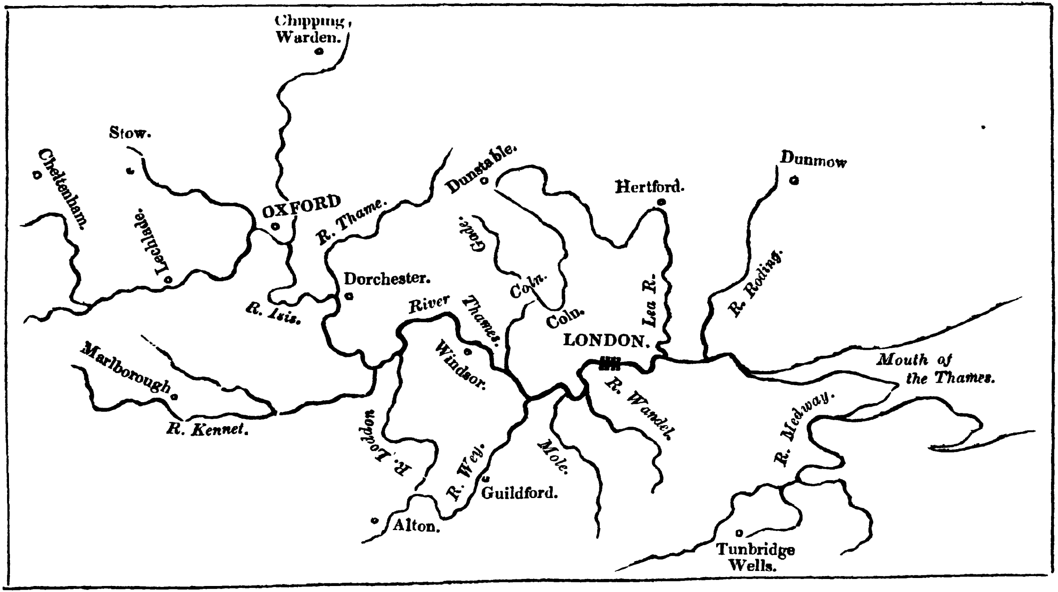
We have seen that when several rivers unite their waters, they form a system of rivers. The Rhine, the Rhone, the Mississippi, the Amazonas, the Thames, all form instances of systems of rivers; and, as the latter will form a very excellent illustration of such a system, and of its divisions and subdivisions, we will select this for an example.

The main or principal stream is designated the *recipient* stream, because it receives the other streams. Such is the main body of the Thames. Rivers which flow into the recipient, are termed *affluent streams**, because they flow towards, and directly into, the recipient stream. Thus the Medway, the Lea, the Mole, the Coln, the Kennet, are affluents of the river Thames. Some of these affluents of the Thames, in their turn, become recipient streams, and have their affluents. Thus we find that the Coln, which enters the Thames near Staines, receives at Rickmansworth the waters of the river Gade. The Gade is, therefore, an affluent of the river Coln; but as it does not flow directly into the Thames, it does not form an affluent of that river, but, in common with all streams of similar character, can only be considered as a *tributary* of the main stream.

In some instances two rivers unite their streams, and the names of both are lost in a new appellation; thus forming what are termed *confluent* streams†. Of this arrangement we also

* From *affluo*, to flow towards.

† From *confluo*, to flow with.


Chipping Warden.
Stow.
Cheltenham.
Lechlade.
OXFORD
R. Thame.
R. Isis.
Dunstable.
Dorchester.
Gade.
Coln.
Coln.
Hertford.
Dunmow
R. Roding.
Lea R.
LONDON.
River Thames.
Windsor.
Marlborough.
R. Kennet.
R. Loddon
R. Wey.
Guildford.
Alton.
Mole.
R. Wandel.
R. Medway.
Mouth of the Thames.
Tunbridge Wells.

meet with an instance in the river-system we are considering; for we need scarcely remind the reader that the Thame and Isis unite their waters, and after their junction the stream bears the name of Thames.

> The noble Thames, and all his goodly traine;
> But him before there went, as best became,
> His auncient parents, namely, th' auncient Thame,
> But much more aged was his wife than he,
> The Ouze, whom men do rightly Isis name;
> Full weake and crooked creature seemed shee,
> And almost blind though eld, that scarce her way could see.

It thus appears that the Thames exhibits all the different conditions of a system of rivers. It is a *confluent* stream, formed by the junction of the Thame and Isis; and under the name of the Thames, becomes the *recipient* of numerous other rivers. It also possesses both *affluents* and *tributaries*, the former directly, and the latter remotely, adding their stores of water to its stream, and contributing to render it, for the purposes of navigation, one of the finest rivers on the globe: a circumstance to which the great metropolis on its banks owes its vast commercial importance. The number of affluents flowing into the river Thames is about twenty; and its tributaries are very numerous. This river thus forms the drainage of a district of country, the superficial extent of which is estimated, as we have before seen, at about 5000 square miles.

It will be evident that the velocity of rivers must, in a great degree, depend on the physical constitution of the country in which they derive their origin, and which they traverse; and also on the nature of the soil through which they pass. They are, therefore, subject to varying conditions, changing with every irregularity of their channels, though, like all other departments of nature, governed by well-defined laws. Of these some notice has already been taken, whilst considering the natural flowing of water.

The river Thames takes its rise at an elevation of only a few hundred feet above the level of the sea; and since its whole course lies through a comparatively flat country, it presents no

instances of torrents, waterfalls, or rapids; a circumstance, however, which renders this stream peculiarly adapted for the purposes of navigation. The fall or slope in the Thames is nearly uniform, being on an average about twenty-one inches per mile; but there are places where the fall varies from nineteen to thirty-two inches per mile. In such localities, some difference of velocity will undoubtedly occur; but the mean velocity of the Thames is estimated at about two miles an hour. The course of the river is very tortuous, it being thus lengthened to nearly double the distance in a straight line from the source to its mouth. The river is navigable for large vessels, as far as London, and for barges to Lechlade, the distance from the latter place to Sheerness being 204 miles. The velocity of the Thames being thus moderate and uniform, and the river free from rapids and cascades, and also passing for a considerable part of its course over a bed of clay, its waters do not become charged in any great degree with earthy or saline matter. Its numerous windings likewise tend to arrest the progress of any foreign ingredients down the stream; and all these circumstances united, are of great utility in maintaining the river in its present condition, to which the configuration and nature of the coast at its embouchure also greatly contributes. The result of these various conditions is of vast importance, for the consequence is, that ships of the largest size meet with no impediments from sand-banks or shoals in the entrance to the river, and thus the largest merchant-vessels, and the largest men-of-war, are capable of approaching the great city; and the river Thames, below bridge, presents in its forest of masts a scene no less striking than gratifying to all who feel interested in the welfare and prosperity of the British nation.

The river Thames, though of such importance, and possessing so many advantages for navigation, is, nevertheless, a very small stream, when compared with the mighty rivers which traverse the continents, whether in the Old or in the New World. The greater number of large rivers have their origin among very elevated mountain-ranges or high table lands; but instances occur of mighty rivers taking their rise in

comparatively low districts. Thus the Volga, which is the largest river of Europe, and has a course of above 2000 miles, derives its source from the lake Ternoff, in the province of Rukof, a district, the most elevated part of which does not exceed 1100 feet above the level of the sea, but which forms the water-shed, not only of the basin of the Volga, but also of that of the Dwina, which falls into the Baltic, and that of the Dnieper, which enters the Black Sea. The Mississippi, again, which is a yet larger stream, originates in a tract, the elevation of which does not exceed 1500 feet; and this forms the water-shed of the rivers which flow from thence into the Arctic Ocean, and also of those which enter the Atlantic by the channel of the great Canadian lakes, and the river St. Lawrence. Rivers of this description generally flow with a moderate velocity, and are frequently navigable throughout their whole course. Such is the case, both with the Mississippi and also with the Volga, the ancient Rha, which latter river thus becomes of the utmost utility to Russia, not only on account of the facility this river affords for water-carriage, but also as it has presented the means of reducing and keeping in subjection the different tribes inhabiting its borders. The ordinary velocity of the stream does not much exceed one mile per hour; but in the spring, after the melting of the snows, the velocity is increased to three miles an hour.

Large rivers, however, as already remarked, most generally have their origin in elevated districts, and in their descent from their sources great variations usually occur in the nature of the country through which they pass, and consequently in the velocity with which they flow. The course of a mighty river of this class has been so prettily compared by Pliny to the life of man, that we cannot forbear adorning our pages with the elegant simile. "The river springs from the earth, but its origin is in heaven. Its beginnings are insignificant, and its infancy frivolous; it plays among the flowers of a meadow; it waters a garden, or turns a little mill. Gathering strength in its youth, it sometimes becomes wild and impetuous. Impatient of the restraints it meets with in the hollows among

the mountains, it is perhaps restless and turbulent, quick in its turnings, and unsteady in its course. In its more advanced age, it comes abroad into the world, journeying with more prudence and discretion, through cultivated fields; and no longer headstrong in its course, but yielding to circumstances, it winds round what would trouble it to overcome and remove. It passes through populous cities, and all the busy haunts of man, tendering its services on every side, and becoming the support and ornament of the country. Now increased by numerous alliances, and advanced in its course, it loves peace and quiet, and in majestic silence rolls on its mighty waters, until it is laid to rest in the vast abyss."

Large rivers, which take their rise in mountainous districts, and which traverse a considerable extent of country before they unite their waters with those of the ocean, are usually considered as forming three distinct parts, or divisions, which are distinguished as their upper, middle, and lower courses; under which separate heads it will be desirable to consider some of their more remarkable features.

The *Upper course* of a river of this class, comprises the part lying within the mountain region in which it takes its rise. The source is mostly at a great elevation above the sea; and the waters flow with a greater or less degree of velocity, according to the inclination or slope of the declivities along which their course lies. When the latter are very steep, the current of the river flows with great velocity, and presents a series of *rapids* and *cataracts;* the former being caused by a continued slope in the bed of a river; and the latter by the occurrence of sudden and precipitous rocks, over which the water falls with a greater or less descent. When such falls are of an impetuous character, they are usually called cataracts; when more gentle, they are termed cascades.

The mountains which constitute the banks of the upper course of such a river, occasionally rise almost precipitously to the height of two or three thousand feet above its bed, so that the stream, instead of flowing through a valley, cuts its

way through a narrow cleft, or ravine; and in such situations, the water frequently runs over bare rocks, without the smallest covering of earth. The course of the river is generally in a straight line; but sometimes it makes short and abrupt bends, which form acute angles. In the latter case, it has been observed that the mountains which enclose the stream almost invariably correspond so closely on either side that they present the appearance of having been rent asunder by some great convulsion of nature. Although on a very small scale, we find an instance of such a cleft, or ravine, in the water-fall of *Poule-Phoca*, in the county of Wicklow. We also meet with a similar zigzag cleft, in the upper course of the river *Danube*. In the latter instance the river completely doubles itself, suddenly and rapidly wheeling round the projecting mass of rock, and entering a defile, the romantic and awful beauty of which, according to Mr. Planché, surpasses all description. "Enormous crags piled one upon another, to the height of from three to four hundred fathoms, their weather-blanched pinnacles starting up amid black firs and tangled shrubs, which struggle to clothe each rugged pyramid from its base to its apex, form the entrance to this grand and gloomy gorge, through which the mighty stream boils and hurries, winding and writhing, till at length you become so utterly bewildered, that nothing but a compass can give you the slightest idea of the direction of its course." Instances of similar clefts are met with in the southern declivities of the Alps, through which the upper course of some of the Italian rivers extend. They are also very numerous among the Andes, especially in their western slopes; and it has been supposed that the term *quebrada*, or "broken," which is applied to the latter ravines, has reference to their peculiar character, and that it was bestowed on them by the Spaniards, on account of the impression which naturally suggests itself of their having been caused by some violent disruption of the mountains in which they occur.

We also meet with an instance of a similar cleft, in the large river *Thlew-ee-choh*, or *Back's river*, which takes its rise in Sussex Lake, and falls into the Arctic Ocean. This river,

throughout its whole course, presents all the characteristics of a mountain stream. Having passed through a series of lakes, it cuts its way through a mountain range, and flows through another lake from which it issues by a series of cascades extending for a mile and a half, and having a descent of sixty feet. It then rushes with fury between four granite mountains, which like immense flood-gates divert its course, and cause it to turn directly northwards. The stream, so lately pent up in this narrow gorge, now becomes from half a mile to a mile wide, and presents a succession of whirlpools and rapids of the most fearful description. It then passes through another lake, and, having taken a leap down a steep precipice, terminates its hurried career in the Arctic Ocean.

The river Thlew-ee-choh, however, can scarcely be considered as belonging to the class of rivers to which our attention is at present directed; for though it presents the characteristics of a mountain stream, it has, properly speaking, no middle or lower course. To return, therefore, to our more immediate subject. We generally find, in the upper course of a river, that the descent of the whole mass is not by a nearly regular slope, but that it usually consists of an alternation of plains and declivities; and it generally happens, that though the rocky banks are sometimes in near conjunction, so as scarcely to allow for the passage of the waters, in others they recede to a greater or less distance from the river, thus forming a basin, or valley; and as the inclination is usually not of so great amount in such localities, the stream flows with a comparatively slow pace, and consequently a deposition takes place, not only of the larger boulders, or masses of rock, which it may carry down with it, but also of sedimentary matter. In valleys of this description, the river accordingly flows over a pebbly bed, whilst, owing to occasional inundations, which spread the finer particles over the adjacent ground, good soil is formed, and the land usually becomes adapted for cultivation.

The alternating defiles, or *narrows*, as they are termed, mostly appear to have been formed by the action of the water in forcing its way through some rocky barrier, which inter-

cepted its onward progress; these usually have a considerable declivity, so that the channel of the river presents a series of rapids and cataracts, and the stream rushes down with extreme velocity.

Some of the rivers which descend from the Central and Eastern Alps, afford striking instances of such alternations of narrow passes and spreading valleys. The river *Reuss*, which is a tributary of the Rhine, (being an affluent of the Aar,) may form our example. This river rises in the St. Gothard group of mountains, at the elevation of more than 7000 feet above the sea-level. Having so great a height from which to descend, it forms numerous rapids and cataracts in the early part of its course. It rushes with almost incredible velocity, through the ravine of the Hospendal, and falls no less than 1800 feet before it reaches the basin, or valley of the Ursern. Across this valley, the surface of which is nearly level, the river flows with a gentle current. At the northern extremity of this little valley, however, the Reuss enters a second defile, called the Narrow of Urnerloch. This narrow, which is about three miles in length, is extremely contracted, and in this confined channel the river descends 1074 feet, forming a series of small cataracts. After some further alternations, this river passes through the lake of Luzern, so greatly celebrated for the picturesque beauty of its scenery, and ultimately joins the Aar, near Brugg.

The river *Colombia*, or *Oregon*, which takes its rise in the Rocky Mountains, and falls into the Pacific Ocean, though it may not present an example of so rapid a descent as some of the mountain streams of the Alps, affords perhaps one of the most striking instances known to exist of a mighty body of water rushing through a contracted channel. After its junction with its affluent, the Lewis river, the Colombia at first expands to a width, varying from one to three miles. In some parts, especially where it attains its greatest width, the river passes over a plain of some extent, whilst in others, this broad and splendid river forms rapids, (locally termed *chutes*,) and even cataracts of some height. The river, which, as we

have just seen, expands to a very considerable width, subsequently arrives at a rocky defile, forming, perhaps, one of the most remarkable narrows, or rapids, on the face of the globe. The channel of the river is here contracted to the width of 150 feet; and through this gorge, the whole body of this mighty river rushes with great velocity. Through this tremendous pass, nevertheless, did Captain Lewis and his party venture down in their canoes, and also arrived at its termination in perfect safety. The vast volume of the water, of course, tends to increase the velocity of the current; but is not without its utility. Were the water less deep, the stream would toss itself in foam and fury over the rocky bed, and navigation would be wholly intercepted. Owing to the great depth of the water, however, the surface is quite smooth, so that this rapid may be passed in comparative security, and the downward navigation of the river is not wholly intercepted. On issuing from this narrow, the Colombia once more expands its waters, and after having flowed across a comparatively level country, ultimately enters the ocean by a mouth more than four miles in width.

Though by no means exclusively, it is chiefly among the mountainous districts which form the upper courses of rivers that cataracts are met with. In a country so comparatively level as South Britain, waterfalls of any magnitude are of rare occurrence; and the only cascade claiming notice in the southern counties of England, is one in the small river *Lyd*. This river is an affluent of

> The speedy Tamar, which divides
> The Cornish and the Devonish confines,
> Through both whose borders swiftly down it glides,
> And meeting Plim, to Plimmouth thence declines.

The beautiful and picturesque waterfall, above alluded to, which is called *Lydford cataract*, has a fall of nearly 100 feet.

In the northern counties, cascades are more numerous. In some parts, they are locally termed *forces*. Such are *Hardrow Force*, *Whitfield Gill Force*, and *Mill Gill Force*, all of which occur in a small river, which joins the Yore, or Ure, near

Askrigg, in Yorkshire. In the fine cataract, called Hardrow Force, the stream precipitates itself over a ledge of rocks, 99 feet in height, after which it rushes through a narrow, or ravine, 900 feet in length; and scarcely has it emerged from this chasm, ere it forms the two other forces, or cascades, abovementioned. In the same vicinity, the river Ure also forms a fine cataract, called *Aysgarth Force*, where the river pours its whole waters over an irregular ledge of rocks, thus forming a series of waterfalls, dashing down amid rugged masses of rock, and bordered by beautiful and richly wooded cliffs. Near Ingleton, in the same county, we met with a cascade of more remarkable character, consisting of a subterranean waterfall, formed by the river *Weare*, which here passes through a cavern, called the *Cave of Wethercot*. This cavern is about 180 feet in length, and 90 broad; its depth being about 100 feet. It is divided into two parts, by a natural arch in the limestone rock. Within this cavern, the stream issues from a large aperture, falling in an unbroken sheet of water, and with a deafening noise, to the depth of 75 feet, when it disappears, and pursues a subterranean course for nearly a mile. Other caverns of similar character, also containing su terranean cascades, occur in the same immediate vicinity; an about three miles from Ingleton, the river Weare forms a beautiful cataract, called *Thornton Force*, which has a fall of about 90 feet in one sheet of water, 16 feet in width.

Waterfalls are of frequent occurrence in Westmoreland and Cumberland, mountain torrents in many parts rushing down the steeps, and forming beautiful and highly picturesque cascades. Among these may be more particularly mentioned *Skelwith* and *Colwith Forces*, near Langdale, *Scale Force*, and *Sour Milk Forces*, in the vicinity of Buttermere, and the *Fall of Lodore*, at Borrowdale; the latter of which has been celebrated in a lively strain by the poet Southey:

> Here it comes sparkling,
> And there it lies darkling,
> *   *   *   *   *
> And spreading and threading,
> And whizzing and hissing,

And dripping and skipping,
And whitening and brightening,

* * * * *

Dividing and gliding and sliding,
And grumbling and rumbling and tumbling,

* * * * *

Delaying and straying and playing and spraying,
Advancing and prancing and glancing and dancing;
And so never ending, but always descending,
Sound and motion for ever and ever are blending,
All at once, and all o'er, with a mighty uproar,
And this way does the water come down at Lodore.

The largest waterfall in England is, however, that in the river *Tees*, the volume of water in this cascade being very considerable. The river is divided in its descent by a projecting ledge of rock, but the waters unite before they reach the bottom, and fall with much force into the basin below, sending up clouds of spray. The wild beauties of the surrounding scenery add much to the effect of this fine cascade.

Wales contains some fine cataracts, especially in the mountainous districts lying between Snowdon and Cader Idris. Among these, the most remarkable are those in the rivers Maw, or Mawddach, and Cayne, which are locally termed *pistils*. The *Pistil-y-Mawddach*, or *Cataract of the Mawddach*, consists of three successive falls, the respective heights being 20 feet, 30 feet, and 20 feet. The *Pistil-y-Cayne* presents a far more magnificent aspect. In the latter, a sheet of water pours down a rugged declivity, 200 feet in perpendicular height, the sides of the fall being thickly mantled in trees. The stream is received, at the termination of its descent, into vast hollows, or basins, which have been scooped out by the long-continued action of the water, and from whence it is again thrown up in clouds of foam.

Scotland contains many picturesque waterfalls. Among these are the falls in the rivers *Tumel* and *Bruar*, both affluents of the Tay; the *Falls in the Clyde*, the *Falls of the Fyers, the Fall of Glomach*, &c. The *Fall of the Bruar* forms

the subject of a poem of Burns, in which he makes the cascade thus express itself:

Here, foaming down the shelving rocks,
In twisting strength I rin;
There, high my boiling torrent smokes,
Wild roaring o'er a linn;
Enjoying large each spring and well,
As nature gave them me;
I am, altho' I say't mysel,
Worth gaun a mile to see.

Owing to the tortuous route it pursues, the river Clyde does not present the characteristics of a mountain stream in the early part of its course; but after its junction with the Douglas Water, or river, it assumes an impetuous character, being precipitated over a succession of cataracts. The first fall, which is near *Bonnington*, does not exceed 30 feet; but the magnificent *Fall of Cora Linn*, which succeeds it, has a perpendicular descent of 70 feet. Four other falls subsequently occur, after which the river acquires the tranquil character which so well adapts it for inland navigation, and for the channel of an extensive commerce. The celebrated *Falls* in the small river *Fyers*, or *Foyers*, consist of two cataracts, called the Upper and Lower Falls, and having an interval of about half-a-mile between them. The Upper Fall is divided into three cascades, whose united height amounts to 200 feet, the river in this part being confined between steep rocky banks. The Lower Fall is on a grander scale; the Fyers in this spot, after dashing through a narrow rocky channel, suddenly precipitating itself over a cliff 212 feet in height; and the combination of bare and rugged rocks with the descending water, and with beautifully wooded heights, where the graceful foliage of the birch prevails, gives rise to a very striking and picturesque scene. The most stupendous cascade in Scotland is, however, the *Fall of Glomach*, in the county of Ross. This is formed by the Girsac, and is situated at the head of a wild glen, where the river is precipitated in one unbroken fall of more than 300 feet.

Ireland contains some fine waterfalls, among which the most remarkable are the Rapids in the Shannon, and the Fall of Powerscourt. *The Rapids in the river Shannon*, near Castle Connel, in the county of Limerick, form a considerable obstacle to the safe navigation of the river, but present a highly picturesque natural object.

The Fall of Powerscourt, which is formed by the river Dargle, is situated in the county of Wicklow, and when the river is full, presents a grand appearance*. The stream precipitates itself over a nearly perpendicular cliff, 300 feet in height, and falls into a natural basin or reservoir, encircled by rocky masses of considerable magnitude, whilst the whole scene is backed by mountains. This fall exhibits rather a singular phenomenon in the different degrees of velocity with which the water descends in different parts of the cascade. Thus, on one side, the water may be observed to pour down with considerable velocity, whilst, on the other side, the fall in the upper part presents the appearance of a continued stream of frothy foam, gliding slowly down the face of the cliff, though the lower part moves with greater velocity. This circumstance is, however, readily accounted for, being, in fact, mainly attributable to the comparatively small body of water which forms the cascade. The water on the one side, that which descends with the greater velocity, (and this forms by far the largest portion of the cascade,) meets with no interruption in its descent, but falls almost from the very top to the bottom, in an unbroken sheet. On the other side, however, the cliff in the upper part deviates from the perpendicular; and the consequence is, that, owing to the slope or inclination of the rock over which it flows, the progress of the water is checked in that particular part, though lower down, where the cliff is again perpendicular, it regains its velocity. If the body of water in this cascade were greater, this phenomenon would not occur; for, in that case, not only would the whole body rush down with greater velocity, but the depth or volume of the stream would overcome these inequalities, and

* See Frontispiece.

a uniform surface thus be presented, as we have before seen takes place in rapids, when the volume of water is great. A beautiful rainbow is occasionally displayed on the spray of this waterfall. It is, however, only visible on summer mornings between five and six o'clock. The prismatic colours are said to be vividly exhibited.

The mountainous character of *Sweden* and *Norway* causes the greater number of the Scandinavian rivers to assume the character of mountain torrents throughout nearly their whole course; and hence, it not unfrequently happens that cataracts are met with very near the mouths of these rivers. Thus, the celebrated *Cataract in the river Dahl*, in Sweden, occurs not far from the embouchure of that river, in the Gulf of Bothnia; and the *Glommen Elf*, or *river*, besides numerous other waterfalls and rapids, forms the *Sarpe Foss*, which has a fall of sixty feet, at the distance of not more than ten miles from its mouth.

Cataracts are very numerous among the mountain masses of the Alps*. Among the most celebrated are those in the river *Reuss*, including that spanned by the so-called *Devil's Bridge;* the *Cataract of Staubbach*, near Lauterbrunn, in the canton of Berne, which has a descent of above 1000 feet; the numerous cataracts in the impetuous river *Arve*, among which the most remarkable is that called the *Nun of Arpena*, said to have a fall of at least 1100 feet; the *Cataract of Ceresoli*, that of *Evanson*, &c. &c. The *Falls of Schauffhausen*, or *Laufen*, in the river Rhine, although they yield to the above-mentioned cataracts in the depth of their descent, which does not exceed seventy feet, far surpass them both in their volume of water, and in their breadth, the Rhine in this part having a width of 450 feet. A projecting mass of rock, situated nearly mid-

* The waterfalls in this region are thus forcibly alluded to by Lord Byron in his Journal. "Arrived at the foot of the Jungfrau Glacier:—torrents,—one of them 900 feet visible descent! . . . . the torrent is in shape curving over the rock like the tail of a white horse: . . . . It is neither mist nor water, but something between both. Its immense height gives it a wave, a curve, a spreading here, a condensation there. Wonderful! indescribable!"

way in the river, divides the falling stream into two parts, but owing to the great volume of water it soon again is united, and falls to the bottom in one broad sheet. With such force does the river rush down the fall, that the spray is thrown up from the rocky basin which receives it, to a very considerable height, forming a dense white mist or cloud, which obscures the prospect, and thoroughly wets the bushes and rocks on the banks of the river, and which, when the sun's rays fall on it, is adorned with a beautiful display of the prismatic colours.

The rivers which have their sources among the *Pyrenees*, also form many fine cataracts in their upper courses. One of the most remarkable of these, on account of the splendid scenery by which it is encompassed, occurs near the source of the *Gave*, or river *de Pau*. Let the reader picture to himself an amphitheatre of solid rock, the walls of which rise perpendicularly to the height of more than 1500 feet, terrace above terrace, and surmounted by gigantic columns, 1000 feet in height, also consisting of solid rock, but the capitals of which are formed by the coronets of snow which never quit their summits. In this remarkable and sublimely grand spot, rushes down the cataract which forms the source of the Gave de Pau. "No other cataract in Europe," observes Mr. Murray, "is equal to it; and no other portion of European scenery can be compared to that which forms its birth-place."

In *Italy*, the most celebrated waterfalls are those of *Tivoli*, and that formed by the river *Velino*. The *Cascades of Tivoli* are formed by the river Anio, or Tiverone, which, after having glided gently through the town of Tivoli, reaches the edge of a precipice, over which it throws itself in two broad sheets, amidst scenery rarely equalled in picturesque beauty: rocky masses, worn into a thousand shapes by the abrasion of the falling water; cliffs fringed with shrubs, and mantled with luxuriant woods, and (thus combining the richest works of art with those of nature) crowned with the beautiful remains of the temple of the sibyl Albunea. In the same immediate vicinity, the Anio forms three other cascades of smaller size,

called the *Cascatelli*, not less celebrated than the preceding for their beautiful scenery, and adorned with the ruins of Mæcenas' villa. The splendid *Waterfall of Velino* is formed at the junction of the river Velino with the Nera, near Terni. About three miles above Terni, the channel of the Velino becomes contracted and inclined; and the impetuous river, after rushing down this confined and sloping channel, terminates its course by a precipitous leap of 300 feet.

> From the headlong height
> Velino cleaves the wave-worn precipice.

The water dashes down in several streams, and coming in contact with the marble rocks, of which the bed of the river is formed, (and to which it owes its name of the *Cascata del Marmore*, or the *Marble Cascade*,) the spray is thrown up to a considerable height, falling again, like a perpetual shower of rain, on the neighbouring valley.

> It mounts in spray the skies, and thence again
> Returns in an unceasing shower, which round
> With its unemptied cloud of gentle rain,
> Is an eternal April to the ground,
> Making it all one emerald.

The volume of water rushing down this fall, united with its great perpendicular descent, renders it a very imposing object; and Lord Byron, who describes it in prose as well as in verse, speaks of the waterfall of Velino as "worth all the cascades and torrents of Switzerland put together." And, (to cite one more passage from the noble poet,) calls it

> A matchless cataract!
> Horribly beautiful!—But on the verge,
> From side to side, beneath the glittering morn
> An Iris sits amid the infernal surge,
> Like Hope upon a death bed!

Among the most remarkable waterfalls of *Asia*, may be mentioned the *Fall of the river Pabur*, a tributary of the Ganges, and the *Cataract of the river Shirawati*, in the province of Canara, in the south of India. The river Pabur takes its rise amid the lofty peaks of the Himalaya mountains, whose giant

forms are in this part displayed in all their grandeur. At the elevation of about 12,900 feet above the sea-level, the river bursts from its bed of snow, which greatly resembles, though on a far larger scale, the glacier which forms the source of the Rhone among the Alps of Switzerland. The Pabur rushes down with great rapidity from this lofty height, and, in its downward course, becomes the recipient of numerous affluent streams, which also have their sources among these magnificent snow-clad mountains. At one point, several small rivers unite, and form a splendid cataract. The stream, rushing over a solid wall of rock, makes only two shoots down to the bed of the Pabur, a distance of about 1500 feet; the upper shoot being the longest. At first the waters continue in a tolerably compact mass, but subsequently they are separated into white foam, and at a lower elevation they become so scattered that even this almost disappears, so that at the distance of half a mile no traces of the mass of water are visible. At a great depth below the scattered drops again unite, and the water re-appears, only, however, to make a second shoot, and to terminate its course in the bed of the river Pabur. The *Cataract in the river Shirawati* is described as "exceeding in beauty and sublimity any waterfall hitherto known to Europeans." The country, at the distance of about three miles from the cataract, presents the richness of tropical vegetation, both in its natural state, and under cultivation. The river breaks suddenly on the view, and, passing over huge blocks of granite, the traveller arrives at the brink of a fearful chasm, rocky, bare, and black, down which he may look to the depth of 1000 feet. The bed of the river is a quarter of a mile in width; though, owing to the elliptical form of the rocks constituting the façade, or edge of the precipice, the extent of the fall is much increased, it thus having a sweep of about half a mile, and forming what is usually termed a *horse-shoe* waterfall. In the rainy season, the river is considered to have a depth of about thirty feet at the fall; and this body of water rushes in a sheet of white foam, at first over a slope at an angle of 45°, for the distance of about 300 feet, and

is then precipitated to the depth of 850 feet more into a black abyss, with a thundering noise. The whole depth of this magnificent cataract is therefore 1150 feet.

In no part of the globe are cataracts more numerous than in the *New World*, whether we direct our attention to the northern or southern portions of that vast continent. We have already considered the character of the Thlew-ee-choh river, with its numerous cascades and rapids. Its near neighbour, Hood's river, much resembles it in this respect, and contains the splendid cataract called *Wilberforce Falls*, which affords a fine example of a double waterfall, and which is described as one of the most magnificent objects in nature. The upper fall has a height of about sixty feet; the lower at least 100 feet: "but," observes Captain Franklin, "perhaps considerably more; for the narrowness of the chasm into which it falls prevented us from seeing its bottom, and we could merely discern the top of the spray from beneath our feet. The lower fall is divided into two by an insulated column of rock, which rises about forty feet above it. The whole descent of the river at this place probably exceeds 250 feet." The walls of the chasm into which the river precipitates itself are upwards of 200 feet high, quite perpendicular, and in some parts only a few yards apart. The river flows through this remarkable chasm for upwards of a mile.

Cataracts sometimes occur in districts which are not mountainous, and which are comparatively level, above as well as below the fall, but having an abrupt descent in that particular locality. Of this we meet with numerous instances in the eastern districts of North America, not only in the stupendous cataract of *Niagara*, but also in the numerous rivers which take their rise in the Alleghany Mountains and flow into the Atlantic Ocean. In the latter region a ledge of rocks extends from north to south, giving rise to waterfalls or rapids in the greater number of these streams. Such are the *Falls of the Passaic* at Patterson, those of the *Raritan* near New Brunswick, of the river *Millstone* near Princetown, the *Delaware* at Trenton, the *Schuylkill* near Philadelphia, the *Brandywine* near

Wilberforce Falls.

Wilmington, the *Patapsco* near Baltimore, the *Potomac* at Georgetown, the *Rappahanock* near Fredericksburg, the *James River* at Richmond, the *Munford Falls* on the *Roanoke*, the *Neure* at Smithfield, the *Cape Fear River* at Averysboro, the *Wateree* near Cambden, &c., &c.

The magnificent *Cataract of Niagara* is formed by the river which receives the accumulated surplus waters of the four great upper lakes,—Superior, Michigan, Huron, and Erie,—and which conveys them into Lake Ontario; the difference in the level of the two lakes being 330 feet. The river Niagara, when it issues from Lake Erie, is about three-quarters of a mile in width, but, before reaching the falls, expands to the width of a mile, and is in this part of its course propelled with great rapidity, being about twenty-five feet deep, and having a descent of fifty feet in half a mile. At the very verge of the cataract, an island, having a width of about 1500 feet, divides the stream into two sheets of water, thus forming two distinct falls. One of them, called the *Crescent*, or *Horse-shoe Fall*, has a width of 1800 feet, and 158 feet perpendicular descent; the other, called the *American Fall*, is about 600 feet wide, and 164 feet in height. The noise, tumult, and rapidity, of this falling sea, the clouds of foam, the vast volumes of vapour, which rise into the air, the brilliancy and variety of the tints, and the beautiful rainbows which span the abyss, the lofty banks, and dense woods, which surround this wonderful scene, are described by travellers as surpassing every similar phenomenon. "'Tis a grand spectacle,—it's the voice of nature in the wilderness, proclaiming to the untutored tribes thereof, the power and majesty and glory of God. It is consecrated by the visible impress of the great invisible Architect. It is sacred ground—a temple not made with hands. It cannot be viewed without fear and trembling, nor contemplated without wonder and awe. HE who appeared of old to Moses in a flame of fire in the bush, and the bush was not consumed, appears also in the rush of the water, and the water diminishes not."

The noise produced by this mighty rush of water, is said to resemble that of the discharge of a thousand pieces of ordnance;

it is also said to be heard, and the clouds of vapour to be seen, at the distance of thirty or forty miles from the spot. The Crescent, or Horse-shoe Fall, descends in a mighty wave of sea-green hue; the other, being broken into foam by projecting rocks, assumes the appearance of a sheet of molten silver. The channel of the river becomes contracted immediately below the falls; and it is a remarkable fact, that in this spot, directly at the foot of this immense rush of waters, a small boat can cross the stream with safety. This is accounted for by supposing that the confluence of the two descending masses of water, which meet at a considerable angle, tends mutually to neutralize the opposing forces. It is also supposed that, owing to the amazing force with which the cataract is precipitated into the bed below, the descending water forms an under downward current, whilst a superficial eddy carries the upper stratum of water back towards the main fall.

These falls afford a magnificent example of the powerful action of running water in destroying and removing rocks. This great sheet of water is precipitated over a ledge of hard limestone, which forms the upper stratum, and beneath which are beds of soft shale. The latter crumbles away more rapidly than the former, and thus the limestone rock is undermined, and forms an overhanging mass, projecting forty feet or more beyond the hollow space beneath. Being thus left without foundation, the calcareous rock falls from time to time in huge masses, and the bed of the river below the falls is strewed over with the huge fragments which have been hurled down into the abyss. By the continual wearing away and destruction of the rocks, the falls have receded about a hundred and fifty feet within the last forty years; and according to Mr. Lyell, "there appears good foundation for the general opinion that the falls were once at Queenstown, (or rather, perhaps, the spot where Queenstown now stands,) and that they have gradually retrograded from that place to their present position, about seven miles distant."

The river *Montmorenci*, an affluent of the St. Lawrence, which river it joins about nine miles below Quebec, presents all the characteristics of a mountain torrent throughout its

whole course, exhibiting a series of rapids and waterfalls, including two magnificent cascades, and passing amid the most varied and beautiful scenery. The great *Fall of the Montmorenci* is described as a singularly striking and beautiful natural object. It certainly bears no comparison to the Falls of Niagara in magnitude, or in the mass of its waters, the stream not having a width of more than 100 feet; but the extremely beautiful foliage of the ample woods with which it is fringed, the broken rocks that surround and intersect its channel, and the singular beauty of the rushing waters, which, after hurrying down an inclined channel, are precipitated to the depth of 240 feet in perpendicular height, combine to render it a more lovely, though less imposing scene. In the winter, this cataract presents a curious and beautiful phenomenon, in the form of a pyramid of ice, 150 or 200 feet in height, caused by the settling and gradual accumulation of the foam and spray on a large mass of ice in the basin immediately in front of the fall.

The river *Missouri* contains a splendid series of waterfalls, called the *Falls of the Missouri*, which are said almost to vie in grandeur with those of Niagara. These falls extend over a distance of nearly twelve miles, presenting a succession of rapids and cascades, including two of considerable depth, and terminating in one of the most magnificent and picturesque cataracts, even in this land of waterfalls. The river at this place is 900 feet in width, and rushes between perpendicular rocks, not less than 100 feet above the surface of the stream. The cataract has a fall of upwards of 80 feet perpendicular height, and, owing to the state of agitation into which the water is thrown by the previous cascades and rapids, it rushes down with extreme turbulence and rapidity. On one side of the cataract, the water pours down in a smooth and even sheet, having a width of about 300 feet; on the other side, however, where it has a width of 600 feet, the water in its rapid descent dashes against irregular and projecting rocks, by which it is broken into snow-white foam, thus causing this portion of the fall to present a singularly splendid appearance. The spray is sometimes scattered in all directions; sometimes thrown up in high

columns, and sometimes collected into large clouds, which the sun adorns with the prismatic colours.

The rivers of *Mexico* abound in cataracts. Rushing down from its elevated table-land, and, (owing to the structure of the country,) reaching the sea after a very short course, they maintain the character of mountain streams throughout their whole career. Among these cataracts, the most remarkable is that of *Regla*, pouring its waters down amid basaltic rocks, fringed with noble and beautiful trees; and described by De Humboldt, as forming one of the most picturesque spots on the face of the globe.

South America affords us some very fine examples of mountain torrents and of cataracts. The celebrated *Cataract of Tequendama* may be more particularly mentioned. This stupendous waterfall is formed by the river Bogota, an affluent of the Madelena. The Bogota, after expanding to a considerable width, subsequently enters a narrow defile, not more than forty feet wide; and after pursuing its course through this contracted channel for a short distance, the river precipitates itself, at two bounds, to the depth of 574 feet. "Independent of the height and size of the column of water," observes M. de Humboldt, in describing the Cataract of Tequendama, "of the character of the landscape, and the aspect of the rocks; it is the luxuriant form of the trees, and herbaceous plants, and their distribution into groups, or into scattered thickets; the contrast of the craggy precipices with the freshness of vegetation, which stamp a peculiar character on these great scenes of nature."

In the mountainous region of *Tierra del Fuego*, at the southern extremity of the New World, we meet with a singularly grand assemblage of waterfalls and mountain torrents. The elevated land in this locality, bordered as it is on three sides by the water of the ocean, attracts and condenses an unusual amount of moisture, and consequently, rain is almost incessant in the lower districts, whilst the more elevated parts contain vast accumulations of ice and snow. In a region of different character, these vast supplies derived from atmospheric moisture, might give rise to large and important rivers; but, bordering as these mountain-ranges do on the very verge of the

ocean, the streams have only a very limited course, and rush down the steeps in the form of torrents or of cataracts. This is exhibited on a magnificent scale, in a spot, appropriately named *Point Waterfall*, situated near the eastern extremity of the Gabriel Channel, in the Straits of Magalhaens. At this place, an enormous glacier has been formed, twelve or fourteen miles in length, which feeds this remarkable group of waterfalls.

> Lo! like a pile of diamonds bright,
> Built on the stedfast cliffs, the waterfalls
> Pour forth their gems of pearl and silver light;
> They sink, they rise, and sparkling cover all
> With infinite refulgence; while their song,
> Sublime as thunder, rolls the dark dense woods along.

Within the space of nine or ten miles, Captain King mentions that there are upwards of 150 waterfalls, dashing into the Gabriel channel from a height of 1500 or 2000 feet. The course of many of these cataracts is concealed at first by intervening trees, and when halfway down the descent they burst upon the view, leaping as it were out of the dense forest. Some unite as they fall, and are together precipitated into the sea, in a cloud of foam. So varied, indeed, are the forms of these cascades, and so great their contrast with the dark foliage of the trees which thickly cover the sides of the mountain, that, as Captain King has observed, "it is impossible adequately to describe the magnificence of the picturesque effect of this very remarkable scene."

CHAPTER XVI.

RIVERS.—MIDDLE COURSE OF A RIVER.—LOWER COURSE OF A RIVER.—DELTAS.—ESTUARIES.

The *Middle* and *Lower Courses* of rivers claim our next attention.

When hilly tracts intervene between the mountain districts and the plains, through which the course of a river lies, these may be considered as constituting its *Middle Course*.

See the rivers how they run
Through woods and meads, through shade and sun,
Sometimes swift, and sometimes slow,
Wave succeeding wave they go,
A various journey to the deep,
Like human life to endless sleep!
Thus is nature's vesture wrought,
To instruct our wandering thought;
Thus she dresses green and gay
To disperse our cares away

In hilly districts forming the middle courses of rivers, we frequently observe a succession of basins, or valleys, the surface of which is usually covered with a thick layer of alluvial soil, caused by accumulations of sedimentary matter deposited during the inundations of the river, and rendering their localities especially adapted for the growth of vegetation. The rocks or hills which form the margins of these basins, generally recede to some distance from the river, but low ridges of rocks connected with those which constitute the lateral margins of the basins, are often met with, at greater or less distances apart, forming the separation between two snch basins, and crossing the bed of the river, usually giving rise to rapids, or other disturbances of the stream. Of this species of formation, we meet with a remarkable example in the river *Dranse*, which falls into the Lake of Geneva; the valley through which the course of that river lies, consisting of a series of basins, one more elevated than another, in each of which occurs a wide expanse of level alluvial land, and each of which is separated from the succeeding basin by a rocky ledge. Such ridges are, indeed, met with in nearly all the principal rivers of Europe. Thus, in the *Rhine*, we find instances of such dividing ridges, at *Bingen*, at *St. Goar*, and at *Andernach*. In the *Danube*, we meet with similar rocky ledges in the celebrated and dangerous rocks, called the *Strudel and Wirbel*, and in those called the *Demir-Kapi*, or *Iron Gate*.

The *Strudel and Wirbel*, in the river Danube, are described by Mr. Planché as consisting of masses of rock and castle, scarcely distinguishable from each other, appearing to rise in

the middle of the stream. "The flood roars and rushes round each side of them; and ere you can perceive which way the boat will take, it dashes down a slight fall to the left, –struggles awhile with the waves,—and then sweeps round between two crags, on which are the fragments of old square towers with crucifixes planted between them. The boat has scarcely righted from this first shock, when it is borne rapidly forward, towards an immense block of stone, on which stands a third tower, till now hidden by the others, and having at its foot a dangerous eddy. The boat flashes like lightning through the tossing waves, within a few feet of the vortex, and comes immediately into still water, leaving the passenger, who beholds this scene for the first time, mute with wonder and admiration. These are the Scylla and Charybdis of the Danube:—the celebrated Strudel and Wirbel." The *Demi-Kapi* or *Iron Gate*, consists of a ledge of rocks extending across the river, seemingly tossed about in wild confusion, and assuming almost every kind of form and position. Over these rocky masses, the water rushes with great impetuosity, forming a series of rapids and dangerous whirlpools, extending for about three miles, and presenting numerous striking and picturesque scenes, but causing a serious obstacle to the navigation of the river Danube.

The rivers of South America also present us with instances of ledges of rocks separating these river basins, and giving rise to rapids and small cataracts. Thus, in the river *Orinoco*, we meet with the rapids, or cataracts, called the *raudales* of *Maypures* and *Atures*. The *raudale* is a peculiar kind of cataract; the great volume of water does not descend at once from a considerable height, like the Falls of Niagara, nor does it rush through a narrow opening between rocks, like the cataract of Tequendema, but the bed of the river is divided into numerous narrow channels by rocks and rocky islets, between which the water runs with great rapidity, forming a succession of small cascades. At the *raudale of Maypures*, the river Orinoco has a width of more than a mile and a half, and this succession of cascades extends for six miles; the highest of these falls does

not exceed nine feet, and the descent in the river is not more than thirty feet in the whole six miles, but the force with which this vast body of water strives to find a passage for itself through these narrow channels, renders it impossible to ascend the stream in this locality. The *raudale of Atures* is of similar character, but only half a mile in length.

In the basins or valleys which intervene between these rocky ledges, or rather in the plains occupying their centres, and along which the course of the river lies, it is a remarkable circumstance, that the highest ground invariably occurs on the very banks of the streams, the land sloping from thence on either side. The *Mississippi* affords an example of such a formation on a grand scale. When this mighty river overflows its banks, the waters, being arrested in their progress, deposit the sediment of mud and sand, with which they are abundantly charged. The coarser and more sandy portion is thrown down nearest the banks, and consequently a more rapid accumulation and growth of land takes place in that part, whilst the finer particles are deposited at the farthest distances from the river, where an impalpable mixture subsides, forming a rich black soil. Hence, in the alluvial plains of the Mississippi, the land slopes back like a natural *glacis*, (or slanting bank of earth in a fortification), towards the cliffs which bound the basin or valley through which the river flows; and, during the annual inundations, the highest parts of the banks form narrow strips of dry ground, rising above the river on the one hand, and above the flooded country on the other. The Mississippi, therefore, presents the appearance of a river, running on the top of a long ridge, or artificial embankment; and to adopt the words of Captain Basil Hall, in speaking of the appearance of this river, near New Orleans, when in its full state, "the swollen river looked so like a bowl filled up to the brim, that it seemed as if the smallest shake, or least addition to it, would send it over the edge, and submerge the city. The footpath on top of the embankment was just nine inches above the level of the river."

Rivers of this class rarely run in a straight line, but

usually take a serpentine, or meandering direction. This circumstance renders the course of a river much longer than if it flowed in a straight line, and consequently the fall, and velocity of the current, in a given distance, will be diminished. The *Mississippi* affords a striking example of this characteristic of rivers, crossing the plain in a remarkably meandering course, and describing immense and singularly uniform curves. So regular, indeed, are these curves, or "bends," as they are locally termed, that the Indians calculate distances by them. The river *Missouri* is equally remarkable for the sinuosity of its course. When Captains Lewis and Clarke were pursuing their way up this river, on one occasion, when they stopped to take their meridian observations, they found themselves so near the spot where they had made their observations on the preceding day, that they sent a man to pace the distance over the narrow neck of land, which separated the two stations. This proved to be only 974 yards; whilst the distance by the river was eighteen miles and three quarters. At a place called the *Great Bend*, or *Grand Detour*, the distance across the neck of land was found to be 2000 yards, whilst the circuit by the river was no less than thirty miles.

The *Lower Course* of a river usually lies through a plain; and generally speaking, no hills occur to form the margin of a basin, though in some instances, low ridges separate the valley through which the stream flows, from that of some neighbouring river. The nature of the soil in such situations is usually soft, and the waters therefore scoop out a passage for themselves. The banks of a river of this kind are very little raised above the surface of the water, and the level character of the ground usually extends to a considerable distance on each side, whilst, owing to the flatness of the country, the fall, or inclination of the river is small, and the current slow. Thus, the surface of the *Elbe* at Hamburgh, that is, about seventy-five miles from its embouchure, is not more than six feet above the sea-level, and the fall in the river very little exceeds an inch per mile.

The course of the river *Amazonas* across the savannahs of Brazil affords a yet more striking example of a river possessing a small degree of inclination in its lower course. This magnificent stream, from the narrow at Olydos, where its middle course terminates, and it enters on its lower course, to its embouchure,—a distance of no less than 700 miles,—does not fall quite twelve feet, that is, little more than a fifth of an inch per mile. It will be evident that, if a small stream were to pass over ground having so trifling an inclination as that above-mentioned, it would, instead of flowing freely onwards, creep with a sluggish pace, and, like the old river Witham, in Lincolnshire, form unprofitable fens and marshes. Owing, however, to the great volume of water carried down by the Amazonas, the current of this superb river is, notwithstanding the small slope of its bed, very considerable, and it pours a vast body of fresh water into the Atlantic ocean.

The surface of a plain which forms the lower course of a river, is, as we have seen, generally covered with a layer of alluvial soil, deposited by the waters during their inundations. The matter of which this alluvium consists, is soft, and loosely bound together; and consequently the current, even though it may be slow, has sufficient power to wear away, and remove portions of the banks from some parts, and to deposit them in others. By such means, great changes are produced in the channels of rivers, in the lapse of time; and if a mass of rock, or other impediment, should occur in the middle of the stream, thus presenting an obstacle to the free current of the river, the latter will be divided into two parts, branching off on either side of the obstacle, whilst accumulations of sedimentary matter will take place round the latter, forming, according to circumstances, either islands, sandbanks, or deltas. The river *Mississippi* exhibits these phenomena on a grand scale, and the changes continually in progress in that river are very remarkable. "Some years ago," observes Captain Basil Hall, "when the Mississippi was regularly surveyed, all its islands were numbered from the confluence of the Missouri to the sea; but every season makes such revolutions, not only in the number,

but in the magnitude and situation of these islands, that this enumeration is now almost obsolete. Sometimes large islands are almost melted away—at other places, they have attached themselves to the main shore, or rather, which is the more correct statement, the interval has been filled up by the myriads of logs, cemented together by mud and rubbish." The process of the gradual formation of islands in the channel of this river, is described with much vividness by Miss Martineau. "A sort of sain on the water, betokened the birth-place of new land. All things help in this creation. The cliffs of the Upper Missouri detach their soil, and send it thousands of miles down their stream. The river brings it, and deposits it in continual increase, till a barrier is raised against the rushing waters themselves. The air* brings seeds, and drops them where they sprout, and strike downwards, so that the roots bind the soft soil, and enable it to bear the weight of new accretions. These islands are seen in every stage of growth. The trees, from being like cresses in a pool, rise breast high; then they are thickets, to whose shade the alligator may retreat; and then they are like the forest itself." Nor does the transporting power of this vast body of water stop here: for it not unfrequently happens, that after the flood season, several acres of land thickly covered with wood are precipitated in a mass into the stream, thus almost at once forming new islands, whilst on the other hand, large portions of those previously formed, are swept away to form accumulations in other localities.

When an accumulation of sedimentary matter takes place at the mouth of a river, forming an island, or mass of alluvial land, by which the stream is divided into two or more branches, this is usually termed a *delta*. The form of an accumulation of this description ordinarily approaches more or less to that of a triangle, the base being turned towards the lake, or sea, into which the river discharges its waters, and the apex towards the flowing stream. The cause of this is obvious.

* And we may add, the water also.

The water, striking against the rock or other obstacle which leads to such an accumulation, diverges into two streams, forming two currents, the one taking a course to the right and the other to the left, thus leaving an intervening space, immediately in front of the rock, more or less of a triangular shape, where no current occurs, and where, accordingly, the comparative stillness of the water causes a deposition of sedimentary matter to take place in that particular form. If, however, an opposing current, arising from the entrance of the tides into the river, or from any other cause, should occur, the water in front of the rock would be agitated, and no deposition would take place. And thus, we find that deltas are not formed in rivers where the force of the stream is not of greater power, than that of the tides and currents which enter their mouths. They are therefore of more frequent occurrence in rivers which discharge their waters into lakes and inland seas, than in those which enter the ocean.

The term "delta" has been bestowed on formations of this description, on account of the resemblance they so frequently bear to the form of the Greek letter Δ, Delta, this appellation having been originally given to such an accumulation in the river Nile. Instances of deltas occur in the Rhone, the Mississippi, the Indus, &c.

Deltas are divided into *Lacustrine*, or such as are formed in lakes; *Mediterranean*, or those formed in inland seas; and *Oceanic*, or those formed on the borders of the ocean.

The *Rhone* affords examples both of lacustrine and of mediterranean deltas; and as this river will present us with a highly instructive and interesting illustration of these phenomena, we will pause to trace it in its course, from its origin among the glaciers of the Alps, to its embouchure in the Mediterranean Sea, a distance of about 540 miles.

The river Rhone, celebrated by Spenser as

> Long Rhodanus whose source springs from the skie,

takes its rise at no great distance from the sources of the Rhine, the Reuss, and the Aar. The source of the Rhone is

situated at the elevation of more than 10,000 feet above the level of the sea, gushing from a stupendous glacier:—

> The glassy ocean of the mountain ice
> . . . with rugged breakers which put on
> The aspect of a tumbling tempest's foam,
> Frozen in a moment.

The river at first presents all the characteristics of a mountain torrent, precipitating itself with great noise and impetuosity into the vale beneath, and indeed consisting of little else than a succession of cataracts. Entering the great valley called the Valais, it rolls its onward course at the base of some of the most splendid mountains of the Alpine range, being augmented, at almost every step of its progress, by numberless streams and torrents, which dash down the declivities of the elevated mountains that form the margin of its grand basin. The course of this river at first lies among hard rocks, and consequently, notwithstanding its impetuous character, it does not become charged with any large proportion of sand, mud, or other extraneous matter; and its waters are therefore, in this part of its course, remarkable for their transparency, appearing of a bluish milk-white hue. As the stream proceeds, however, the nature of its channel changes, and passing among softer rocks, it bears down a considerable quantity of detritus; the consequence of which is, that its waters become turgid, and when they approach the upper end of the Lake of Leman, or Geneva, they are greatly charged with sedimentary matter. The Rhone enters with considerable impetuosity into this beautiful lake, discolouring its waters for some distance; but the placid expanse of water ere long calms down the turbulence of the river, and the waters of the latter being stilled, deposit a vast amount of sand and mud, which, rapidly accumulating, forms a delta at the mouth of the river, presenting one of the most remarkable known instances of the formation of a lacustrine delta. The growth of land in this locality has been very great; an alluvial tract, more than a mile and a half in length, having been acquired in this manner in about eight centuries; a fact proved by the present situation of the town called Port Valais, which

in the tenth or eleventh century, stood at the water's edge, but is now a mile and a half inland. The accumulation is still as much in progress as ever, and threatens (though the time required to accomplish this would be very great), ultimately to fill up the Lake of Geneva. The more recent part of the delta consists of a flat plain, about six miles in length, very little raised above the water, being composed of sand and mud, and full of marshes; whilst beneath the waters of the lake, the accumulated sedimentary matter may be traced, sloping down into its bed, with a very slight and gradual inclination.

When the Rhone issues from the Lake of Geneva, the whole of the sedimentary matter it had carried down with it from the Valais, having been deposited in the bed of the lake, its waters are beautifully clear and transparent, and present an azure tint, similar to that exhibited by the waters of the placid lake itself. Scarcely, however, has the river quitted this reservoir, ere its clear waters are again rendered turbid, and filled with sand and sediment, by receiving the waters of its affluent, the impetuous Arve, which brings down annually a vast quantity of granite detritus from Mont Blanc. The current of the Arve is so powerful, that for some time after its junction with the Rhone, its waters do not mingle with those of the latter river, a phenomenon which may be distinctly traced, owing to the different hue of the two streams; and after the melting of the snows, the body of water sometimes brought down by the river Arve is so great, that it overpowers the downward current of the Rhone, and actually forces that river back into the Lake of Geneva; and on some occasions, it has caused the undershot water-wheels on the banks of this portion of the latter river, to revolve in a direction contrary to that in which they ordinarily move.

The Rhone subsequently receives other vast contributions of transported matter, brought down by its several affluents, but more especially by the Saone and the Doubs, both of which carry down a large quantity of detritus from the Vosges and Jura mountains; whilst the Isere and Durance also contribute their share from the Alps of Dauphigny. The Rhone

thus becomes so greatly charged with sand and mud, that when at length it enters the Mediterranean, it discolours the blue waters of that sea, with a whitish sedimentary matter, for the distance of between six and seven miles, throughout the whole of which area, the current of fresh water is perceptible; and it further appears that to the same distance, the deposition of sedimentary matter is rendered evident, by the gradual sloping of the bed of the sea in this locality, which, according to a recent survey by Captain Smyth, gradually deepens from 24 to 240 feet.

It will be readily supposed, that the vast quantity of foreign matter thus annually carried down by the Rhone and its tributaries, will lead to the accumulation of land at its embouchure; and accordingly, we find that it contains a delta, which commences at Arles, where the river is thus divided into two branches, between which this alluvial formation is enclosed. The growth of this delta has been very rapid; Psalmodi, which was an island in the year 815, being now six miles from the shore; and the tower of Tignaux, which was erected close to the water's edge in 1737, is already about three miles from the shore.

By the confluence of the stream of the river Rhone with the currents of the Mediterranean, when the latter are driven by winds from the south, sand bars are formed across the different mouths of the river, and thus, *lagoons*, or lakes, are formed, subject to the occasional ingress of the river, in seasons of flood, and to that of the sea during storms, and which accordingly, alternately consist either of salt or of fresh water lakes, until, becoming filled up by sedimentary matter, they are converted into salt marshes. Some of these lagoons, being, from their situation, more subject to the ingress of the sea than to that of the river, and being thus continually furnished with supplies of salt water, their waters, in consequence of the evaporation which takes place, become salter than that of the sea; and sometimes a considerable deposition of salt occurs in these natural salterns.

Deltas are formed in many of the other rivers of Europe

which have their embouchure in its inland seas. The vast quantity of detritus annually brought down by the river *Po* and its tributaries, has led, as we have already seen, to large accumulations in that part of Italy: similar formations are also in progress on the shores of the Baltic, where many of the rivers, by their deposits of fluviatile mud, have converted some parts of the sandy wastes of Northern Germany, into rich alluvial tracts. Of this we meet with instances in the *Vistula*, the *Niemen*, and the *Nieper*.

Oceanic deltas are, as has already been stated, of less common occurrence; the mouths of rivers which enter the open sea, and which are consequently exposed to the influence of the tides, generally presenting phenomena of a different class. Under such circumstances, indeed, it frequently happens, that so far from deltas being formed, a loss of land occurs, because the ocean forces its way into the river's mouth, and sweeps away some portion of the shores, penetrating into the land beyond the general coast line, and forming an *estuary*. Wherever, however, the volume of fresh water brought down by a river is sufficiently great to counteract the force of tides and currents, oceanic deltas are produced. Of such formations we meet with instances in the *Indus*, the *Ganges*, the *Orinoco*, &c.

The *Delta of the Indus* commences at the distance of about 110 miles from the sea, which it enters by eleven mouths, presenting a face of 125 miles to the ocean. At the distance of about ten miles from the sea, this delta assumes the character of a thick jungle, frequently forming the resort of tigers, gavials, and other wild animals: a little higher up it is covered with tamarisk shrubs, and the remainder presents a bare plain of hard caked clay. The course of the waters intersecting this delta is perpetually changing, and one year one mouth will be dry, and another in the following. At the time of the late Sir Alexander Burnes' visit, the Gora was the most considerable mouth, but, owing to sand-banks near its entrance, it was inaccessible to ships.

We have seen that *estuaries* are very commonly formed at

the mouths of rivers which have their outlets in the main ocean. The term estuary is in fact applied to the mouths of rivers into which the tides of the sea enter. Outlets of this description have a tendency to become *silted up*, or filled up with sand, mud, &c.; but such a formation differs materially from that of a delta. The latter, as we have seen, is formed by the detritus carried down by the river from the upper lands through, which its course extends; but the silting up of an estuary is in great measure caused by the wasting of the adjacent shores, and the forcing of these crumbling materials into the mouth of the river, by the tides and currents of the ocean. By such means, by the silting up of the river *Yare* in Norfolk, some thousands of acres have been gained for the purposes of cultivation; but this, or any similar formation, cannot be regarded as indicative of any actual increase of land, for, although, as in the casé above alluded to,

> Where the mighty Ocean would not spare,
> There has he, with his own creation,
> Sought to repair his work of devastation;

yet the gain of useful ground, scarcely forms a compensation for the losses sustained on other parts of the same shores. The mode in which this transfer, (for such it may be considered,) takes place, is as follows: the cliffs of Norfolk, especially those between Weybourne and Sherringham, and those near Cromer, are continually falling to decay, by the action of the sea. The marine current, sweeping along the coast, and being charged with the *débris* of these wasting cliffs, is ready to deposit this sedimentary matter, and to form a bar in any situation, the moment its onward course is interrupted by an opposing stream, or current. This it encounters in the river Yare, which, although it has not sufficient force to maintain an open channel for its own waters, has nevertheless power enough to check the progress of the sedimentary matter, and hence sand-banks of considerable size are thrown across the estuary of that river.

It will be evident, from what has just been stated, that formations of this class cannot extend beyond the general line of coast; whereas, deltas, on the other hand, form *projecting*

masses of new land, actually added to the shores by the agency of water, and in most cases, of permanent duration.

Some rivers which fall into the ocean, and have estuaries at their mouths, are subject to a great swell, or sudden rise of the waters, when the tide enters the river. This phenomenon, which occurs especially at spring tides, is usually called the *bore*. The cause of this sudden swell is readily explained. The rise of the sea at spring tides, forces a great volume of water into the wide mouth of the estuary. If, then, the latter be confined between high banks, so that the water cannot escape laterally, and if it become gradually lessened in its dimensions, the water, on entering the contracted portion of the estuary, not being able to flow with rapidity equal to its volume, up this less capacious channel, and also, at the same point, encountering the downward current of the river, a sort of concussion takes place, and the water suddenly accumulates and rises in a heap, sometimes acquiring a height of several feet above the surface of the stream, and rushing with a tremendous noise against the current for a considerable distance. This phenomenon occurs in some rivers in Great Britain, and more especially in the *Severn*, *Trent*, and *Wye*. In the two former rivers, it is called the *Eagre*, or *Uygre*. It is displayed on a larger scale in the estuary of the *Gironde*, where the influx of the tide, meeting the descending waters of the Garonne, gives rise to this phenomenon, there called *Le Mascaret*. In the Gironde, indeed, it is not only of frequent occurrence, but of fearful aspect; and boats are in great danger of being carried from their moorings, and swamped by this sudden swell of the waters. Instances of the bore are also met with in the *Ganges*, the *Escquibo*, the *Amazonas*, &c.

In the *Ganges*, at Calcutta, the bore sometimes causes an *instantaneous* rise of five feet, which would occasion great damage among the smaller vessels afloat in the river, if it did not, owing to local peculiarities, take its course along one bank only; and were it not also preceded by a considerable noise, so that the small craft, having thus timely warning of its approach, may generally be safely removed to the other side of the river,

or at least to the middle of the stream, where, indeed, the swell is considerable, but not so sudden as to endanger vessels which are skilfully managed.

In the river *Esequibo*, as well as in the *Berbice*, the *Corintyn*, and other rivers of Guiana, this phenomenon is of frequent occurrence. In the two former rivers, it assumes a fearful character, rising twelve or fifteen feet, and dashing violently against any obstacle it may encounter. In the Corintyn the phenomena presented are somewhat different, the bore occurring in successive starts of minor elevation. Thus, Mr. Schomburghk observed a bore in the latter river, three feet in height, which dashed violently against the shore, and which was repeated three times, making in all nine feet. The various tribes inhabiting the coast of Guiana, regard this phenomenon with superstition, and usually bestow on it some appellation, signifying "head of waters," or more literally, "mother of waters;" and they have many traditional stories to relate of the *Lakuqui-yahu*, *i. e.*, "mermaid," or "water-sprite," or, as they render it, "water mama."

This phenomenon is displayed on a grand scale near the embouchure of the river Amazonas. The tide ascends that river to the distance of between 400 and 500 miles from its mouth; and when the tide begins to ebb, and the receding waters of the ocean permit the egress of the pent-up waters of the river, the Amazonas at spring-tides pours forth an immense volume of water into the Atlantic, and owing to its augmented volume, the stream enters the ocean with very great velocity. At no great distance from the land, this mighty rush of waters encounters an oceanic current, which, passing Cape Roque, skirts the north-eastern coast of Brazil. These two streams, or currents, meet nearly at right angles, and the violence of the concussion gives rise to the bore or mascaret, called by the Indians the *Pororoca*, on a grands cale, it being asserted, that a mountain of water is by this means sometimes raised to the height of 180 feet. Fishermen and navigators, as we may well suppose, fly from it with the greatest terror, and it is said that it even causes all the adjacent islands to tremble.

We have already taken some notice of navigable rivers, and of the advantages accruing from these natural channels of inland water communication; but we cannot conclude our review of the lower courses of rivers, without again recurring to the subject. We cannot, indeed, pause to consider all the principal rivers on the earth's surface:—

> Great Ganges; and immortal Euphrates;
> Deepe Indus; and Meander intricate;
> * * * * * * *
> Oraxes, fearèd for great Cyrus' fate;
> Tybris, renownèd for the Romaines' fame;
> Rich Orinochy, though but knowèn late.

We must therefore content ourselves with a brief allusion to a very limited number of the most important navigable streams.

The river Thames has already engaged some of our attention; claiming, as it does, the pre-eminence among British streams. And perhaps few scenes are more striking than that presented by the Port of London, (*i.e.*, the portion of the river extending from London Bridge to Deptford, a distance of about four miles,) filled, as it perpetually is, with forests of masts arrived from, or bound to, almost every part of the globe; forcibly reminding us of the following lines of Pope, and perhaps affording their realization beyond the anticipations of the poet himself:—

> The time shall come, when free as seas and wind,
> Unbounded Thames shall flow for all mankind;
> Whole navies enter with each swelling tide,
> And seas but join the nations they divide;
> Earth's distant ends our glory shall behold,
> And the New World launch forth to meet the Old.

But although the Thames is by far the most important river in the British Isles, it is surpassed in size by the *Shannon*. The latter river also possesses the unusual advantage of being navigable throughout its whole extent, from its source in Lough Allen to its embouchure, a distance of 240 miles. The rapids near Castle Connel, offer, it is true, some obstacle to the safe passage of vessels in that part of the river, but this impediment to navigation has been overcome by a short canal; and from the

attention that has recently been paid to the removal of some shoals and sand-banks which had accumulated in the bed of the river, there is reason to hope that this fine stream may, ere long, become the scene of the extensive traffic for which it is so well adapted; and thus, in conjunction with the canals alluded to in a former page, may prove instrumental in ameliorating the fertile island in which it forms so conspicuous an ornament.

In turning our attention to the Old Continent, including Europe, Asia, and Africa, although many noble and highly important navigable rivers occur, no stream exists in the whole of that extensive area, which will bear comparison with the Chinese river Yang-tse-Kiang, either in the length of its course, the capabilities it presents for the purposes of navigation, or in the practical use which has been made of those advantages. Indeed, as a recent author has observed, "If you consider the countless canals which it supplies with water, to keep under irrigation the surrounding country, the commerce which it carries on its breast, and the fruitfulness displayed on its banks, where the richness of the foliage and the greenness of the herbage are quite astonishing; if lastly, you add the depth and volume of its waters, it has some claim, I conceive, to the very first place among the rivers of the globe." The tide ascends the Yang-tse-Kiang for more than 200 miles; and the river discharges itself into the Yellow Sea by a broad estuary, in the centre of which is the island of Tsong-ming, which is of alluvial formation, and is continually increasing in extent, owing to the vast amount of sedimentary matter annually brought down by the river. The present dimensions of the island have been estimated at above sixty miles in length, and eighteen in breadth. It is considered as the largest island of alluvial formation on the surface of the globe, and forms one of the most densely populated districts of China. The inhabitants of this remarkable country, indicate their regard for their noble river, by the appellation they bestow on it, namely, "the First-born of the Ocean."

But although, as has just been stated, the Yang-tse-Kiang

appears to be without a rival in the Old World, it is surpassed in magnitude by some of the mighty rivers of America. In that portion of the globe, "Nature," as has been well observed by a foreign traveller*, "has formed her works on a gigantic scale. Where else is to be found a mountain range like the Andes? where rivers like the Amazonas and the La Plata? where such extensive plains, and almost impassable and boundless forests? Those rich and fertile provinces situated near the foot of the eastern declivities of the Andes, abounding in useful and precious productions, yet bounded as they are on the one side by that tremendous barrier the Andes, might seem to labour under the greatest disadvantages. But the same HAND that has raised the most wondrous and in all appearance impassable barrier to the progress of man in these vast regions, has not omitted to provide safe and convenient means of communication with their remotest parts. The innumerable rivers which have, as it were, burst a path through these almost boundless forests, and which are for the most part navigable, are but so many highways which Nature herself has opened through rocks and mountains and impenetrable forests, for the safe and convenient passage of man and for the transport of the fruits of his industry."

Among the rivers to which allusion is here made, the Amazonas holds the first rank. The direct line of this magnificent river, from its junction with its affluent the Ucayali to its embouchure, is 1600 miles, throughout the whole of which it is considered capable of receiving vessels of the largest size. The Ucayali is also a noble and important stream; free from impediments to navigation; and this river, in conjunction with its affluent the Apuremas, is said to be navigable as far as Mantaro, only 400 miles distant from Lima. And thus, by means of this mighty system of rivers, might a water communication be formed almost across the continent. The region traversed by the Marañon or Amazonas, consists of one immense plain, gradually and almost insensibly sloping down to the Atlantic; not, however, perfectly flat, but rather presenting a

* Thaddeus Haenke.

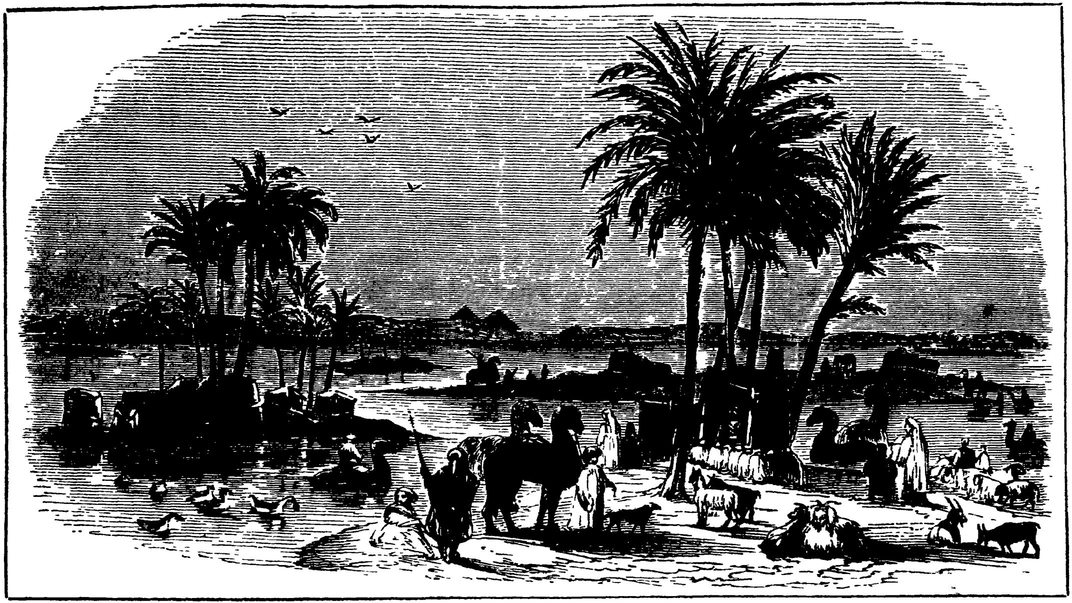
succession of slight undulations covered with the most luxuriant vegetation. No cataracts, no rapids occur, to interfere with the navigation of this mighty stream, which in this portion of its course has an average width of from one to two miles, though nearer its embouchure, it expands to the width of about thirty miles.

The only impediment to navigation in the Amazonas, appears to be presented by the vast quantities of drift wood, brought into its stream by its tributary the Madera, and which render it at times rather dangerous for canoes and small boats. Two German travellers, named Spix and Martius, who some years since ascended this river in a canoe, were exposed to great danger, from the vast quantity of drift wood constantly propelled against their vessel by the current. The tops alone of some trees appeared above water; others had their roots attached to them with so much soil, that they might be compared to floating islets. On these the travellers relate that they saw "some very singular assemblages of animals, pursuing peacefully their uncertain way in strange companionship. On one raft were several grave looking storks, perched by the side of a party of monkeys, who made comical gestures, and burst into loud cries on seeing the canoe. On another was seen, a number of ducks and divers sitting by a group of squirrels. Next came down, upon the stem of a large rotten cedar tree, an enormous crocodile by the side of a tiger-cat, both animals regarding each other with hostility and mistrust, but the saurian being evidently most at his ease, as confident of his superior strength.

The vast capabilities for inland navigation afforded by the rivers of South America, have not, it is true, hitherto been taken advantage of to any great extent. Not so, however, those of the northern portion of the New World; there the noble rivers by which it is intersected, and more especially those included in the basin of the Mississippi, have been turned to the most profitable account, navigation being by this means carried into the very interior of the continent. "It is impossible," observes Mr. Stevenson in speaking of the Ohio, "it is impossible to convey to the reader an adequate idea of those

Most rivers are subject to an occasional increase in the volume of their waters, regulated in great measure by the seasons; and therefore more or less periodical. In the rivers of our own island, these flood seasons, or *freshets*, as they are termed, are partly dependent on the melting of the snows, and partly on occasional heavy falls of rain; in a climate so variable as that of Great Britain, this increase of the waters is subject to great variation, both as to its amount and its periodicity. In countries which possess more *excessive* climates, that is, where the changes from heat to cold, and from cold to heat, are more sudden and more regular, as is the case with most continental regions, these flood seasons in the rivers assume a more periodical character. Thus the *Volga* receives a vast access of water at the melting of the snows in the spring, usually beginning to rise in March, increasing during April and May, and continuing above its usual mark, until the end of June, when it decreases very fast. The common course of the stream, is considered scarcely to exceed one mile an hour, but at the time of the floods, it amounts to three miles an hour.

In regions where the rains are periodical, the increase in the volume of the rivers usually corresponds with these seasons. Thus, in the *Ganges*, the waters begin to increase in April, when the rains commence in the mountains in which it has its



Inundation of the Nile

sources; the rate of its increase is about three inches daily, until the month of July, when the rains descend in torrents in the plains. The increase of the river is then more rapid, amounting to about five inches daily, and the country along its banks for a hundred miles, at that period presents the appearance of a vast lake, interspersed with insulated villages and groups of trees. The general depth of the waters spread over the country in this district is about twelve feet, but in some parts not less than thirty feet. The *Indus*, the *Euphrates*, the *Tigris*, all have their periods of increase of volume, dependent on the setting in of the rains on the mountains in which these rivers originate.

The rise, and consequent inundations of the river *Nile*, have long been celebrated; the land of Egypt, in fact, owing its fertility wholly to this circumstance. Shortly after the commencement of the rains on the mountains of Abyssinia, in which it has its sources, the river begins to rise. This usually takes place in the middle of June, and the waters continue to increase until the end of August, or beginning of September; the whole valley of Egypt, and the greater part of the Delta, being at this period covered with one sheet of water. As the fertility of this district is wholly dependent on the inundations of the Nile, the inhabitants watch for the arrival of the waters with great anxiety; and for the purpose of ascertaining the height of the waters, a gauge, called the *Nilometer*, has been constructed. This is situated in a mosque in Old Kahiro, and consists of a large square tank or well, in which is fixed a granite pillar, divided into karats or digits. The water of the river is admitted at the bottom of the well, and the rate of increase indicated by the digits on the pillar. The rise of the waters is irregular, but its usual progress is from two to four inches daily. When it attains its wonted height, the Nilometer is under water. At Kahiro the greatest rise is twenty-eight feet. When the waters are drained off from the surface of the land, and occupy only their usual channel, the soil which has thus been moistened and enriched by the alluvial deposits, becomes singularly adapted for cultivation, and bears the most

luxuriant crops; this region, which, but for this important river, would consist of a desert waste, being thus rendered one of the most fertile on the surface of the globe.

The periodical overflowing of the river *Matina*, in Central America, though on a comparatively small scale, is remarkable on account of the vast deposits left by its waters. The annual inundation of this river appears to be caused by violent rains occurring in the mountains in which its early course lies. The waters usually rise in the night, and spread themselves over the whole valley or basin of the river, to the depth of about nine feet. This inundation is not, however, of long duration, usually lasting only for twenty-four hours, though sometimes, but very rarely, for thirty-six hours. The waters deposit annually a layer of mud, three or four inches thick, and thus the valley becomes gradually filled up, its surface being much higher than formerly; and as the land in the valley becomes more elevated, the river scoops out for itself a deeper channel, and the extent of the inundation is diminished. The inhabitants of the valley of the Matina, are not wholly without warning of the approach of the waters, for, on the morning preceding the inundation, the atmosphere presents a most threatening aspect, and a succession of squalls usually pass over the district, so that an opportunity is thus afforded for the removal to more elevated ground, of live stock, or any property liable to be injured by the rise of the waters. It will be evident, that these inundations are not without their utility, the deposits left by the waters being of extreme benefit to vegetation, and imparting to it a remarkable degree of vigour and luxuriance.

In large river-basins, like those of the *Mississippi* and *Amazonas*, where the tributary streams, as well as the principal or recipient stream, each have their vernal flood seasons, the volume of water carried down by the several rivers, if they all rose simultaneously, would cause the most fearful inundations, submerging and devastating all the lower parts of the great valleys. But by a wise and admirable arrangement, the periodical rising of the tributary streams, follows each other at

The Nilometer.

considerable intervals. In the river-system of the *Mississippi*, this is attributable to the different periods at which the ice breaks up, and the snow melts, according to the different latitudes in which the rivers take their rise; whilst in that of the Amazonas, it is due to the different times at which the periodical rains fall near the sources of the several tributary streams. Thus, in the basin of the Mississippi, the flood of the Red river precedes that of the Arkansas by about a month. The Arkansas, again, on account of its rising in a more southerly latitude than the Missouri, takes the lead of the latter river in its annual flood season; whilst the superabundant waters of the Missouri are disgorged and disposed of, long before the breaking up of the icy barriers of the northerly region, in which the Mississippi itself originates.

Equally admirable is the arrangement in the river system of the *Amazonas*, though at the same time considerable difference exists in the means by which it is effected. The volume of water poured into the Amazonas by its numerous affluents, is immense; and did all these rivers rise simultaneously, the consequences would be most fearful; by the admirable arrangement above alluded to, however, this evil is effectually guarded against. Some of the *southern* affluents of the Amazonas, among which are the Xingu and the Tapajos, originate in an elevated table-land, situated at no great distance from the Tropic of Capricorn, whilst its *northern* affluents traverse extensive tracts of country bordering on the Equator. In these different latitudes, the periodical rains occur at different times, and hence the flood seasons take place at different periods in the northern and the southern affluents. Thus, the Xingu and Tapajos attain their greatest height, and contribute the largest body of water to the Amazonas, from November to January; whilst the Madera, and the other northern affluents, are fullest from July to September. The importance of this beautiful arrangement will be obvious, when we consider, that, notwithstanding the waters are thus kept within due bounds, the difference between the high and low level of the Amazonas, is not less than forty feet.

The number of considerable rivers which fall into the sea in different parts of the Old Continent, is computed as amounting to 440; and those of the New Continent as not exceeding 140. This seeming disproportion is attributable to the different configuration of the two continents; the vast river-basins in the New World, causing the waters to collect into one mighty channel before they enter the ocean; and the lesser number of the American rivers is amply compensated by their larger volume; many of the affluent streams in the New World, being of much greater magnitude than any of the rivers of Europe.

Several attempts have been made to compute the quantity of water which rivers discharge into the ocean; but, in the present state of our knowledge, all such estimates can only be regarded as mere approximations. It is supposed, that not above one-third of the atmospheric water which descends to earth, finds its way by this means into the ocean; a circumstance which has in great measure been proved by observations made in the basin of the river Seine. To accomplish this, the amount of atmospheric moisture falling in the valley, or basin, drained by the Seine, was first ascertained, and then compared with the volume of water carried down by that river; and from these observations it appears, that two-thirds of the atmospheric water which falls to earth on that area, either is applied to the support of animal and vegetable life, or is returned to the atmosphere by the process of evaporation, or else is absorbed by the thirsty soil, probably, in some instances, finding its way to the sea by subterranean channels. And, from the estimated amount of rain, snow, dew, &c., falling on the surface of the whole of the land on the face of the globe, it has been computed that about 12,757 cubic miles of water may be considered as the annual tribute of the rivers of the globe to the great deep.

COMPARATIVE LENGTH OF THE PRINCIPAL RIVERS.

Name.	Source.	Length in Miles.	Mouth.
Forth	Ben Lomond	100	North Sea.
Severn	Plinlimmon	220	Bristol Channel.
Shannon	Lake Allen............	240	Atlantic Ocean.
Thames	Cotswold Hills	240	North Sea.
Po	Monte Viso	380	Adriatic Sea.
Ebro	Mountains of Asturias.	400	Mediterranean Sea.
Seine..........	Côte d'Or Mountains ..	430	English Channel.
Oder	Carpathian Mountains	500	Baltic Sea.
Tagus	Sierra Morena	530	Atlantic Ocean.
Rhone	Monte Furca..........	540	Mediterranean Sea.
Loire	Mont Gerbier	590	Bay of Biscay.
Elbe	Sudetic Mountains	600	North Sea.
Vistula	Carpathian Mountains.	640	Baltic Sea.
Gambia	Heights of Foota Jallo .	650	Atlantic Ocean.
Rhine	Mont St. Gothard	810	North Sea.
Don	Toula	950	Sea of Azof.
Senegal	Heights of Foota Jallo .	950	Atlantic Ocean.
Colombia	Rocky Mountains	1000	Pacific Ocean.
Dnieper	Heights of Smolensk ..	1100	Black Sea.
Orinoco	Sierra de Parima......	1400	Atlantic Ocean.
Euphrates	Mountains of Armenia.	1500	Persian Gulf.
Ganges........	Himalaya Mountains .	1500	Bay of Bengal.
Danube	Black Forest	1700	Black Sea.
Indus or Sind .	Himalaya Mountains .	1700	Indian Ocean.
Mackenzie	Rocky Mountains	1700	Arctic Ocean.
St. Lawrence ..	Upper Canada	1900	Atlantic Ocean.
Volga	Heights of Valdai......	1950	Caspian Sea.
La Plata	Heights of Itambe	2000	Atlantic Ocean.
Jenesei	Altai Mountains	2200	Arctic Sea.
Hoang-ho	Desert of Cobi	2400	Pacific Ocean.
Lena	Altai Mountains	2500	Arctic Sea.
Obi	Altai Monntains	2500	Arctic Sea.
Nile	Donga Mountains	2700	Mediterranean Sea.
Yang-tse Kiang	Desert of Cobi	3000	Pacific Ocean.
Amazonas . ..	Andes	3200	Atlantic Ocean.
Mississippi and Missouri	North American Lakes Rocky Mountains	3500	Gulf of Mexico.

CHAPTER XVII.

LAKES.—INLAND SEAS.

We have before seen that great advantages arise from internal reservoirs of water, which, being screened from the action of the atmosphere, and thus protected from evaporation, are preserved in the interior of the earth, ready to afford abundant supplies of water, both to natural springs and artificial fountains. We have seen that the results of this admirable arrangement are of the highest importance; we shall also find that the subjectof our present consideration—external reservoirs of water, or *lakes* and *inland seas*,—will afford us another instance of the beautiful adaptation of the earth's surface to the created beings of which it forms the habitation. For, though on the one hand, it is a circumstance of extreme importance in the economy of nature, that some collections of water should be so placed, as to be preserved from decrease by means of evaporation, yet, on the other hand, the very circumstance of the existence of lakes, or external collections of water, which are exposed to the process of evaporation, is also productive of especial benefit, particularly in some localities, on account of the moisture thus raised into the atmosphere, from whence it is ready again to descend in the form of dew, or of refreshing showers; to effect which, in any important degree, a considerable extent of surface will be required. Large lakes are, therefore, of especial utility in regions remote from the ocean: and if we inspect a map of the world, we shall perceive that it is precisely in such situations, that the greater number of large lakes and inland seas occur. Thus, we meet with the largest internal sheets of water on the face of the earth, in the most central parts of Asia, and in the middle districts of North America; the former being more especially remarkable on account of their constituting the reservoirs, or recipient basins, into which rivers of large size empty their waters, but being apparently unprovided with an outlet; so that there is reason to suppose, that the whole of their super-

fluous waters are carried off by evaporation. To this class belongs the Caspian Sea.

Lakes are of different kinds. Some may be considered as tanks, or reservoirs, which receive the first outbreakings of a spring; and in lakes of this description, if the volume of water issuing from the spring be of small amount, the evaporation from the surface may be sufficient to dispose of the whole supply, and therefore such a lake will require no outlet. If, however, the volume of water sent forth by a spring should be considerable, it will form a channel for itself, at the margin of the lake, and issue forth as a stream of greater or less magnitude. Of this description is *Itascu Lake*, which forms the source of the Mississippi, and also the *Lake of Lauricochi*, in which the Marañon, or Amazonas, originates.

Other lakes consist of basins, or reservoirs, which occur in the line of a river's course, into which its waters flow, and in which they accumulate, until they have found their level in the depression which forms the bed of such a lake, when they pour forth their superabundant supplies at some outlet, either occurring naturally, or which they have scooped out for themselves at the other extremity. A stream may thus form numerous lakes in its course, of which we meet with a striking example in the river Mississippi, which, in the early part of its course, expands into and flows through no less than eight such lakes, some of which are of considerable magnitude.

Lakes not unfrequently combine the characteristics of the two preceding classes; forming the passage of a river, and also at the same time being fed by springs, which considerably augment the volume of their waters.

Some lakes consist of basins, or hollows, into which one or more rivers pour their waters, but which, owing to the depression of the region in which they are situated, possess no outlet for the superfluous waters, the latter being either absorbed by the porous soil, or carried off by evaporation. Of this description is the *Sea of Aral*, in Central Asia, which receives several large rivers, including the Sihon and Gihon, (the ancient Jaxartes and Oxus,) but has no visible outlet.

Saline lakes, or lakes the water of which s strongly impregnated with saline matter, are by no means of uncommon occurrence. When springs or streams containing saline matter enter such a basin, the purer portion of the water being carried off by evaporation, the saline particles are left behind in the remaining waters, which thus sometimes become very strongly impregnated with saline matter, especially if they have no outlet for their waters. Of this description are *Lake Asphaltites*, or the *Dead Sea*, the Lakes of *Kahhisar*, *Ourmia*, &c.

Lakes are sometimes formed in the craters of extinct volcanos, and the waters of such lakes are often strongly impregnated with sulphur and bitumen. To this class belong the Lakes of *Nemi* and *Averno*.

Some lakes are periodic; that is, are subject to have their basins alternately empty and full of water. One of the most remarkable lakes of this description is that of *Zirknitz*, in Carniola. This lake is about eight miles in length, by two in breadth. In the early part of June, its waters disappear through several crevices or fissures in its basin, when the peasantry in the neighbourhood hasten to take advantage of the rich pastures which grow there spontaneously, or proceed to cultivate its bed, sowing in it their crops of buckwheat and rye. These crops ripen, and are carried, before the return of the water, which usually takes place about the end of September, or beginning of October, at which time again it makes its appearance, spouting through the apertures in the bed of the lake, with great force. The Lake of Zirknitzis situated in a valley amongst a range of limestone hills, a description of formation frequently found to contain subterranean caverns of great magnitude; and the phenomenon we are at present considering, is accounted for by supposing that some caverns of this kind exist, forming the beds of subterranean rivers; and that, when augmented by the autumnal rains, these rivers flow into a channel which affords them an outlet in this lake; but, on the other hand, when these subterranean rivers are low, the water disappears from the Lake of Zirknitz.

The lakes of our island are in general of small extent. *Winandermere*, or *Windermere*, which is the largest English lake, does not exceed eleven miles in length, whilst its breadth varies from half a mile to a mile. The lakes of *Keswick*, or *Derwentwater*, and *Ullswater*, although they surpass Winandermere in wild and varied scenery, are inferior in size to that lake; and the other lakes of this district, *Coniston*, *Grassmere Buttermere*, *Cromack*, *Westdale*, *Ennerdale*, &c., are of yet smaller dimensions. The western parts of England, and more especially Cheshire, abound in broad shallow sheets of water, called *meres*, which have not sufficient depth for the purposes of navigation, but usually contain abundant supplies of fish. Such are *Oakmere*, *Combermere*, *Bartonmere*, and the beautiful *Ellesmere*. Lakes are very numerous in Norfolk and Suffolk, the greater portion having been formed by the silting up of the ancient bay, which at one period existed in this part of the coast. These lakes, some of which, however, are of very small size, are upwards of sixty in number. Among the largest are *Fritton Lake*, and *Breydon Water*.

Among the rocky basins of the mountainous region of Wales, called Snowdonia, lakes of small size are very abundant: and the darkly shadowed little *tarn*, or lake, near the summit of *Cader Idris*, presents an admirable example of a mountain lake. The largest lake in this principality is, however, *Bala Lake*, called by the Welsh, *Llyn Tegid*, or the *Fair Lake*, and sometimes spoken of by the less attractive name of *Pimble mere*. This lake is remarkable for the purity of its waters, in which, it is said, that the nicest chemical tests have not been able to detect any foreign admixture.

The Scotch lakes, or lochs, are on a somewhat larger scale than those of South Britain. *Loch Lomond*, which is the largest lake in Great Britain, covers an area of about 20,000 acres; its length is twenty-two miles, and in one part it has a width of nine miles, but its breadth is very variable. The numerous and beautiful islands with which this lake is studded, the long richly wooded promontories stretching far into the lake, the cultivated hills to the south, and the lofty mountains to

the north and east, including the elevated summits of Ben Voirlich and Ben Lomond, form a combination of scenery not surpassed by any other spot in the island. Towards its northern extremity, this lake has a depth of 600 feet. *Loch Tay* is a narrow sheet of water about fourteen miles in length and a mile in width, but supposed in some parts to have a depth of 600 feet. *Loch Katrine,* though of less magnitude, is of too great celebrity to be passed wholly unnoticed.

> With promontory, creek, and bay,
> And islands that empurpled bright,
> Floated amid the lovelier light;
> And mountains that like giants stand,
> To centinel enchanted land.

The most remarkable lakes of Scotland, are, however, those forming the long line, or chain of lakes, which extend in a diagonal direction across the Great Caledonian Glen, stretching nearly from one coast to the other. This chain of lakes includes *Loch Ness*, *Loch Oichy*, *Loch Lochy*, *Loch Eil*, and *Loch Linhhe.* Loch Ness is remarkable for its depth, which in some parts is considered not to be less than 800 feet; so that its bed appears to be about 100 feet lower than the bottom of the North Sea, off the eastern coast of Great Britain, even where it is deepest. This lake is never frozen over, a circumstance which is attributed to its great depth; congelation, as we have before seen, not readily taking place in deep water.

The principal lakes of Ireland are *Lough* or *Lake Neagh*, and the beautiful *Lakes of Killarney.* Lough Neagh is the largest lake in the British Isles, its length being about eighteen miles, and its breadth about eleven or twelve. This lake is wholly deficient in picturesque beauty, its shores being low and flat, and in some parts marshy, and subject to occasional inundations. Differing thus in character from the beautiful Scotch lakes, we may expect that it will also differ in the depth of its basin; and accordingly we find, that in no part does the depth of this lake exceed 102 feet. The waters of Lough Neagh, according to some accounts, possess petrifying

or mineralizing properties: whilst according to others, they exhibit no such peculiarity. In all probability this discrepancy has arisen from the occurrence, in some particular locality, of a calcareous, or other mineral spring in the lake, imparting to the waters in that especial part, this peculiar property, but not of sufficient power to affect the whole body of water contained in the lake.

Lakes are very numerous in the northern parts of Continental Europe. They abound in Norway, Sweden, and Lapland, many of the lakes in those parts having a considerable elevation above the level of the sea. In Finland, they are so exceedingly numerous, that the natives themselves bestow on that territory the appellation of *Suomemna*, or "the region of lakes." Not less distinguished for its lakes, is the northern part of European Russia, numerous large sheets of water occurring in that locality, among which is the Lake of *Ladoga*, which is the largest European lake, its length being nearly 120 miles, and its width in some parts 70 miles. It covers an area of more than 6500 square miles, or nearly 500 square miles more than the whole county of Yorkshire. The depth of this extensive sheet of water varies greatly; in some places being said to have a depth of 900 feet, whilst in others it is not sufficiently deep for the navigation of large vessels. The drainage of a very extensive tract of country flows into the Lake of Ladoga, and its only outlet is the river Neva.

Lakes are very numerous in the mountainous region of Switzerland, some of them being situated at a great elevation above the sea level. Among the latter are the small lakes of *Toma* and of *Sera*, which form the sources of the leading branch of the river Rhine, and which are situated in the St. Gothard group of mountains, at the elevation of about 7500 feet above the sea. The Rhine, having descended several thousand feet, passes through the *Lake of Constanz* or *Constance*, called also the *Boden Sea*. This lake is about forty-five miles in length, and its extreme breadth is thirteen miles; its average depth is 320 feet, but it is said that in some places a line of 2130 feet is

required to reach the bottom. The lake of Constanz is subject to the phenomenon of the sudden rising of its waters. Thus, it appears that in the year 1549, the waters rose four or five times in the course of an hour to the height of two or three feet above its ordinary level; and in the year 1770 it rose in one hour, from twenty to twenty-four feet above its usual level. Like other alpine lakes, it uniformly increases in summer, by the melting of the snows on the adjacent mountains, and its lowest period is in winter, when its sources are locked up in ice. Owing to the great depth of its waters in some parts, this lake is rarely frozen over; instances have, however, occurred of its being covered with a sheet of ice. Above fifty streams of considerable size empty their waters into the Lake of Constanz, but the Rhine forms its only outlet.

The *Lake of Geneva*, or *Leman Lake*, extends in the form of a crescent, its northern banks forming an arc about fifty-three miles in length, and its southern one of forty-three miles; its length, however, is usually estimated at about thirty-seven miles, and its greatest breadth at about eight or nine miles. Near its western extremity, this lake becomes greatly contracted, and for about fourteen miles, its width scarcely exceeds one mile. This narrow portion, which extends from Nyon to Geneva, is more especially distinguished by the appellation of the Lake of Geneva, and is sometimes called the Little Lake. The depth of this sheet of water varies considerably in different parts; in some places not exceeding 100 feet, whilst in others it is not less than 980 feet.

> Lake Leman lies by Chillon's walls:
> A thousand feet in depth below
> Its massy waters meet and flow;
> Thus much the fathom line was sent
> From Chillon's snow-white battlement.

The lake, like that of Constanz, is higher in summer than in winter, the difference sometimes amounting to six or eight feet. The Lake of Geneva is subject to a phenomenon, called the *Vaudaise*, which consists of a subaqueous wind, rising to

the surface, and producing an agitation of the waters, which sometimes renders the navigation of the lake dangerous. The phenomenon called the *Seiches*, which consists of an occasional sudden undulation, or rising of the waters, is also not uncommon in this lake, usually not exceeding a few inches in height, though sometimes attaining that of five feet.

Mountain lakes are very numerous among the upper valleys of the Pyrenees; they are, however, never of any great size, but many of them, on account of their great elevation, are covered with ice throughout the greater part, if not the whole of the year. Thus, the *Lake of Mont Perdu*, which is situated at the elevation of 8393 feet, is usually frozen over until the end of August; whilst the *Lake d'Oo*, situated near the Port or Pass d'Oo, and the elevation of which is 8800 feet, is perpetually covered with ice.

The *borax lakes* or *lagoons of Tuscany* present phenomena, perhaps unique in their kind. They occur in the volcanic region of Monte Cerboli, and are spread over a surface of about thirty miles. "As you approach the lagoons," observes Dr. Bowring, "the earth seems to pour out boiling water, as if from volcanos of different sizes, in a variety of soil, but principally from chalk and sand. The heat in the immediate adjacency is intolerable, and you are drenched by the vapour, which impregnates the atmosphere with a strong, and somewhat sulphureous smell. The whole scene is one of terrible violence and confusion—the noisy outbreak of the boiling element—the rugged and agitated surface—the volumes of vapour—the impregnated atmosphere—the rush of waters—amid bleak and solitary mountains." This place was formerly regarded by the peasantry as the entrance to hell, "a superstition," says Dr. Bowring, "derived no doubt, from very ancient times, for the principal of the lagoons, as well as the neighbouring volcano, still bear the name of Cerboli (*Mons Cerberi*). The peasantry never passed by the spot without terror, counting their beads, and praying for the protection of the Virgin." Nor were these lagoons without real and posi-

tive dangers, for the loss of life was certain, when either man or beast had the misfortune to fall into any of those boiling baths. Within a very few years, however, these borax lagoons have been brought into profitable action, and the quantity of boracic acid produced, varies from 7000 to 8000 pounds per day; and the extensive application of this substance to manufacturing purposes, renders its production an object of great importance*. And thus, to use again the words of Dr. Bowring, "these lagoons, which were fled from with terror by uninstructed man, have, in great measure by the exertions of one spirited individual†, been converted into a source of wealth more valuable perhaps, and certainly less capricious, than any mine of silver, that Mexico or Peru possesses;" and promise to "gather round them a large and intelligent population, and to become sources of prosperity to innumerable individuals through countless generations."

The *Lake of Averno,* which in ancient times was celebrated for its sulphureous exhalations, appears no longer to exhibit similar phenomena. The mephitic vapours, or in other terms, the volumes of carbonic acid gas, emitted by *Lago Amsancto,* have been of more permanent duration; a circumstance readily accounted for; the former lake occupying the crater of an extinct volcano, which has gradually ceased to emit sulphureous vapours, whilst Lago Amsancto is situated in a limestone rock, from which exhalations of carbonic acid gas are continually issuing. Over a large portion of the small lake Amsancto, the water, owing to the escape of this gas, is continually bubbling up, with a noise resembling distant thunder, though it is not thrown up above two feet in height. The water is of a dark ash colour. This lake is of classical celebrity, under the name of Lacus Amsanctus, and also that of Lacus Mephitis. Thus it appears that Cicero speaks of the "deadly" character of Lake Amsanctus, and Pliny mentions that

* Borax is chiefly used by workers of metals as a flux, that is, to promote the fusion of those substances.

† M. Lasdarel, on whom the Grand Duke of Tuscany has conferred the title of Count de Pomerance.

there is a spot near the temple of Mephitis*, where whosoever entered, died. There is also a small pool, or lake, adjoining the Lago Amsancto, which is called the *Coccaio*, or *cauldron*, on account of its presenting the appearance of being in a constant state of violent ebullition. On the surface of this little pool, masses of carbonic acid gas are continually floating in rapid undulations, described as being so dense, that they are visible at the distance of 300 feet from the spot. This is supposed to be the *Specus horrendum*, or *direful cave*, mentioned by Virgil. These remarkable lakes appear still to present the same deadly character they did eighteen hundred years ago; the noxious gases they emit, sometimes proving fatal to the inhabitants of the adjacent district, especially when borne by the wind in one direction; but, as the specific gravity of carbonic acid gas is greater than that of atmospheric air, it will not, if undisturbed, rise more than three feet above the surface of the water. A man standing erect, is therefore, in calm weather, not exposed to much danger; but should the face be placed near the ground, a very short time would suffice to cause suffocation; and sheep, straying to the spot, not unfrequently are killed by the mephitic vapour of these lakes.

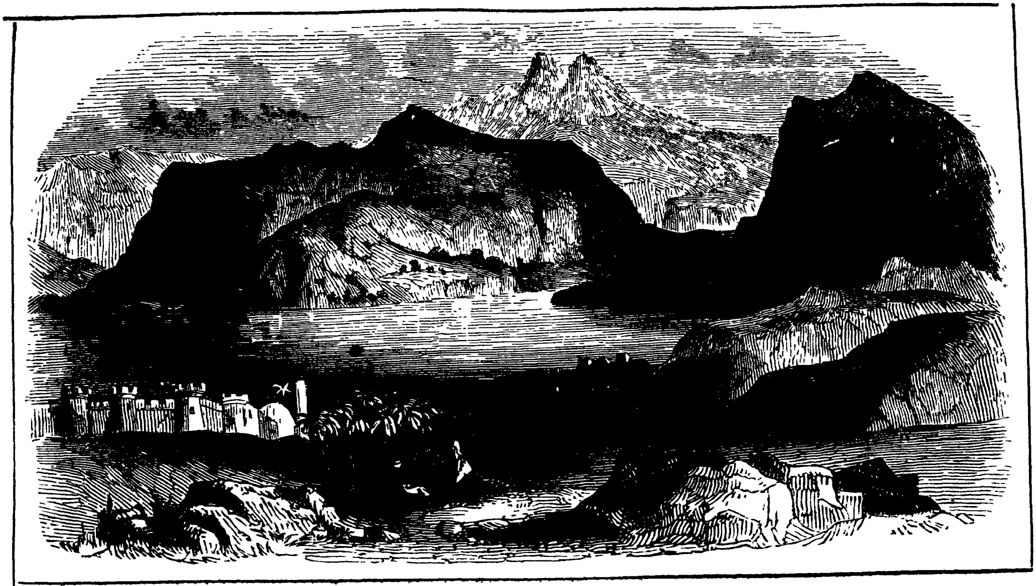
Lakes and inland seas form a remarkable feature in the central parts of Asia. Some of these sheets of water are of very considerable magnitude, and the greater number are remarkable for the saline nature of their waters, which are salter than those of the ocean. Of the latter peculiarity, we meet with a striking instance in the *Lake of Kah-hisar*, in Asia Minor. This lake, which is about 90 miles in circumference, is, perhaps, one of the saltest lakes in existence; and Mr. Hamilton mentions that "its bed consists of a thick solid crust of salt, and the waters are so extremely salt, that no fish or other animal can live in it; birds dare not touch the water, for their wings become instantly stiff with a thick crust of salt." Not less remarkable for the saline qualities of its waters, is *Lake*

* Mephitis was the name of a goddess who was invoked by the Romans as their protectress against noxious vapours.

Ourmia, or *Ourumia*, called also *Lake Shahey*, near Tabriz, in Persia. This lake is about 80 miles in length, and between 20 and 30 in width; and its waters are so strongly impregnated with salt, and so much more saline than those of the ocean, that, whilst 1000 grains of sea water do not contain more than 42 grains of saline matter, the same quantity of the water of Lake Ourmia contains 223 grains. Its specific gravity is, accordingly, much greater than that of sea water; and it is asserted, that a vessel of 100 tons burden, when loaded, does not draw more than from three to four feet, in this sheet of water. A strong gale of wind raises the waves only to the height of a few feet; and as soon as the storm has passed over, the waves almost immediately subside. So buoyant, indeed, is the water of this lake, that it is said a man may actually float on the surface, without danger of sinking. This extreme saltness of the waters of this lake, renders it unfit for the habitation of fish; but some of the lower orders of animals, among which are a few molluscs, small crustacea, and radiated animals, find in its saline waters an abode congenial to their habits.

The *Sea of Galilee*, called also the *Lake* or *Sea of Tiberias*, the *Sea of Chinneroth*, and the *Lake of Gennesereth*,—the modern *Bahr-el-Tabairish*,—though by no means so salt as the two preceding lakes, may be included among the saline lakes of Asia. This lake is supposed to occupy the crater of an extinct volcano, and is about 15 miles in length, whilst its breadth varies from 6 to 9 miles. The scenery of this lake is described as exceedingly beautiful; it is surrounded by mountains, and, like other lakes so situated, is subject to sudden gusts of wind, which render the navigation unsafe, so that it not unfrequently happens that the lives of those who cross its waters may be "in jeopardy." It contains abundance of excellent fish; and would therefore seem to be a place particularly adapted for the abode of fishermen.

The most remarkable of the salt lakes of Asia, is, however, *Lake Asphaltites*, or the *Dead Sea*, which is designated in Holy Writ by the various names of the Salt Sea, the Sea of



The Sea of Galilee,

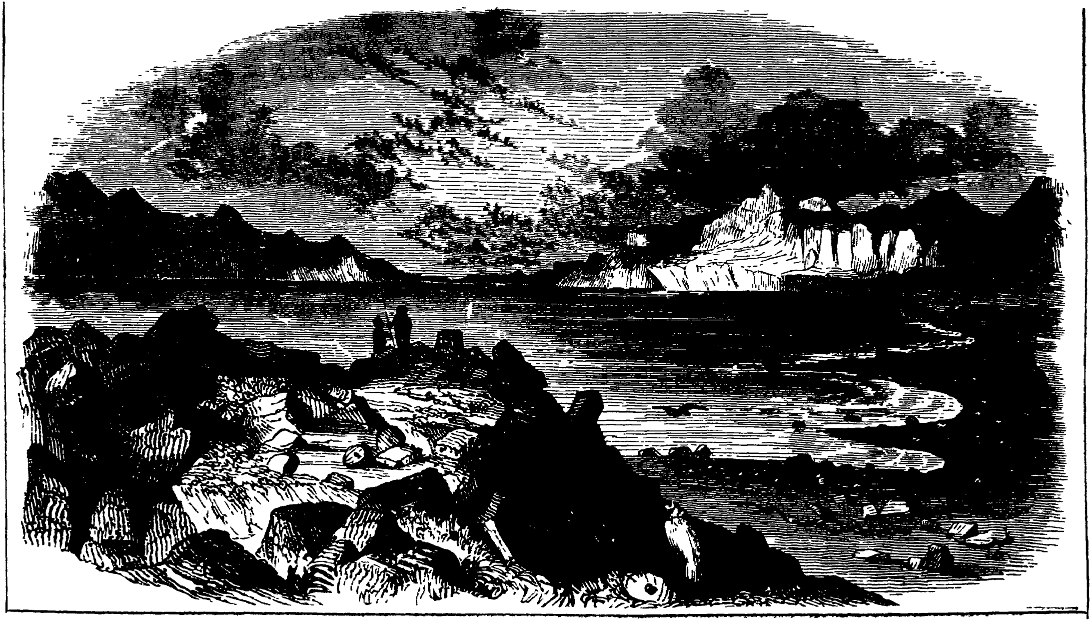
the Plain, and the East Sea. The Romans bestowed on it the name of Lake Asphaltites on account of the abundance of asphaltum which is found on its shores, and also floats on its surface. It is called by the Arabs Bahr-el-Lut, or the Waters of Lot. The length of this lake is about 50 miles, its greatest breadth about 25 miles; and it is supposed that at the period of the destruction of the guilty cities of the Plain, its extent was considerably increased. The country immediately surrounding the Dead Sea is described as presenting scenery of the most dreary and desolate character. On its eastern shores, the lake is bounded by a perpendicular wall of black rock, casting its sombre shadow on the still waters, whilst on the western borders of this gloomy sea, a range of limestone and sandstone cliffs extends, assuming the most fantastic and varied forms. This lake presents an object of awe and amazement to all who visit its shores. Its waters are pungent, salt, and bitter; these, as well as the soil on its shores, being so strongly impregnated with salt, sulphur, and bitumen, that no plants can thrive on its banks, no cattle can drink of its waters. And hence it is, that this lake assumes that character of total desolation, which has obtained for it the name of the Dead Sea; hence, that it presents the dreary and fearful aspect, which might be expected to mark a region under the malediction of Heaven. The surface of the Dead Sea is singularly still: a circumstance, probably, in great measure attributable to the absence of living and moving creatures; but, perhaps, also in some degree arising from the great specific gravity of its waters, which therefore, as we have seen in the instance of the Lake of Ourmia, do not yield so readily to the influence of breezes passing over its surface.

The wind blows chill across those gloomy waves;
  Oh! how unlike the green and dancing main!
The surge is foul, as if it rolled o'er graves:
  Stranger! here lie the cities of the Plain!

The waters of the Dead Sea contain even more saline matter than those of the Lake of Ourmia, being found to contain no less than 384 grains of saline ingredients in 1000 grains

of water; and hence it leaves a saline crust on any substance with which it comes in contact. The water is, nevertheless, perfectly clear, and nearly of the same colour as that of the ocean. This remarkable sheet of water is said to contain no fish; but, perhaps, this circumstance has not been fully ascertained; and that it is not absolutely devoid of all living creatures, appears from the fact of a few shells having been found on its shores by late travellers. The Dead Sea is situated in a remarkable depression, its surface being 600 feet lower than that of the Mediterranean Sea. It receives the waters of the Jordan, those of the river Arnon, and those of the little river or brook of Cedron, or Kidron, but has no visible outlet. The superfluous waters must, therefore, either be carried off by evaporation, or be drained from the lake by some unknown subterranean channel.

The vast salt lake, or inland sea, called the Caspian Sea, is about 700 miles in length, and its breadth about 210 miles. Its depth varies considerably, shallows occurring in some parts, whilst in others the depth of water exceeds 600 feet. The Caspian Sea, like the Dead Sea, is situated in a depression, though not of so great amount as the latter, the surface of the Caspian being 101 feet below the level of the ocean. This inland sea, however, appears to be subject to some fluctuations in the level of its surface; but whether these consist solely in the gradual lowering of its waters, or, as asserted by the inhabitants on its shores, of a periodical rise and fall, yet remains to be proved. The former would perhaps appear more in accordance with probability; especially as it has been inferred from various careful observations, that, at some remote period, the Caspian Sea was of much larger extent, than at the present day. It has, indeed, even been supposed, that in some former era, its waters were in one direction united with those of the Black Sea, the line being still indicated by Lake Elton and some lesser lakes; whilst in the other direction the Sea of Aral is supposed to have formed part of this vast inland sea, and further, that, by means of a continuous series of small lakes which extend nearly from the Sea of Aral to the Arctic Sea, a communication may have



The Dead Sea.

existed between the Black, the Caspian, and the Arctic Seas. The volume of water poured into the Caspian by the Volga, and its other numerous affluents, must undoubtedly be very considerable; it has, however, no visible outlet; and to account for the disposal of its superfluous waters, it has been supposed that these are carried off by a subterranean channel; though it is asserted by others, that the evaporation from this extensive surface, comprising an area of 147,000 square miles, is sufficient to account for their disappearance. The northern portion of this inland sea is annually covered with ice. It is extremely salt, and abounds with fish; and also contains several species of seals.

The Sea of Aral, like the Caspian, is situated in a depression of the earth's surface, and, like that, is very salt, and also abounds with fish, similar to those inhabiting that inland sea. Its length is about 200 miles, and its breadth about 100 miles.

The Lake or *Sea of Baikal* differs from the Asiatic lakes we have been considering, in its waters being perfectly fresh. Its length is about 360 miles, and its greatest breadth about 50; it is singularly variable in its depth, which is said in some parts to be more than 3000 feet, but suddenly to shoal to 150 feet. Its waters are remarkable for their green tint. This lake is surrounded by mountains, imparting to it a grand and imposing aspect. It is regarded with peculiar reverence by the uncivilized nations in its vicinity, who confer on it the appellation of *the Holy Sea*. The waters of Lake Baikal are subject to very singular movements, which are supposed to be occasioned by earthquakes. Even when the most perfect calm prevails, vessels are sometimes so greatly agitated by an apparently subaqueous disturbance, that it is difficult to stand in them. The surface is indeed rarely without an undulation. This undulation, called by the sailors *kolychen* or *zyb*, increases on the approach of a breeze, this increase taking place about an hour *before* the wind arrives, and the undulation proceeding from the quarter whence the wind blows. A moderate breeze violently agitates the surface, whilst a storm produces comparatively little effect upon it.

Many other lakes of considerable size occur in Central Asia; but we can now only pause to mention the *Borax Lakes* of Tibet. The borax obtained from these lakes is imported into Europe in the form of crystals, and under the commercial name of *tincal*.

The interior of Africa is so little known, that it is impossible to give any certain statement relative to its lakes or inland seas. One vast lake, or inland sea, it is, however, known to possess in the *Lake Tchad*, which is the largest fresh-water lake in the known world. This extensive sheet of water, called by the natives the *Bahr el Soudan*, and which forms one of the grandest features of the territory of Bornou, is considered to be 200 miles in length, by 150 in breadth; but in the rainy season it becomes greatly enlarged, and encroaches considerably on its flat shores.

The celebrated *natron* or *trona* lakes of Egypt appear to be in great measure dependent for their supplies of water on the periodical inundations of the Nile. These lakes are situated in a valley forming a portion of the western desert which borders on Egypt. They are six in number, and are placed in succession along the valley, being separated from each other by barren sands; the whole line occupies a length of about sixteen miles, though scarcely in any part attaining the width of one mile. These lakes are, as just stated, apparently supplied with water from the river Nile, the water flowing into them abundantly, and oozing chiefly from the banks adjacent to that river, at the period of its rising, but decreasing with the subsidence of its waters. The heat of the sun causing the remaining portion of water to evaporate, a thick crust of natron, or carbonate of soda, is deposited in the bed of the lakes, usually attaining the thickness of two feet, and being very hard. It therefore would appear, that the soil through which the water percolates, must be strongly charged with this substance, which by this means is brought to the surface ready for the use of man. The natron thus deposited is collected once a-year, and is used both in Egypt and Syria, as also in many parts of Europe, for the

manufacture of glass, and likewise for bleaching linen, and as a substitute for soap. The natron or carbonate of soda produced by these lakes appears to have been applied to similar purposes, at least the two latter, in very remote ages; and the substance spoken of by the prophet Jeremiah* as a means of purification, and rendered "nitre" in our translation of the Bible, is supposed to be the natron of these Egyptian lakes. The same salt is also supposed to be referred to in the book of Proverbs, in the following passage: "As vinegar upon nitre, so is he that singeth songs to a heavy heart;"† allusion being here evidently made to the alkaline nature of the natron or soda, and its effervescence with an acid; an effect which would not be produced by nitre.

Dr. Andrew Smith, in his expedition into the interior of Southern Africa, obtained information from the natives, which would lead to the conclusion of the occurrence of a large fresh-water lake, about three weeks' journey to the north of the Tropic of Capricorn. The statements made in regard to this lake were vague and unsatisfactory, excepting as to its existence; on this point no discrepancy occurred. The appearances of the sheet of water were so naturally detailed by the natives, and the form of the boats, and the manner of making them "walk," so minutely and clearly detailed, as proved at once that all must actually have seen what they thus attempted to describe.

In the New World, nature appears to have formed all things on a grand scale, a remark which applies as well to the lakes of America, as to her rivers and mountains. With regard to our present subject of inquiry, however, the northern portion of the continent claims the pre-eminence over the southern, the latter containing no lakes of importance, with the exception of the *Lake of Titicaca*, or *Puno*, in Peru, remarkable for its elevation of 12,000 feet above the level of the sea; and the *Salt Lakes*, near the base of the Andes in the basin of La Plata. One of the latter lakes, called the *Laguna de Salinos*, distant about 450 miles from Buenos Ayres, is always filled with salt, and for-

* Jeremiah, iii. † Proverbs, xxv. 20.

a chain of minor lakes. Great Slave Lake is about 200 miles in length and 100 in breadth. This large sheet of water communicates with *Athabasca Lake* by Slave River, which is again connected with *Lake Winnipeg* by a chain of smaller lakes. Lake Winnipeg, which is of a winding form, is about 280 miles long, and its width varies from 15 to 80 miles. Besides numerous other important streams, Lake Winnipeg receives the river Saskatchawan, one branch of which issues from a lake situated among the defiles of the Rocky Mountains, this lake being remarkable for forming the source, not only of this river, which flows into Lake Winnipeg, and thence into Hudson's Bay, and thus finally into the Atlantic, but also of another copious stream, which, being a tributary of the Colombia, ultimately finds its way to the Pacific Ocean.

The most remarkable hydrographical feature of this region is, however, presented by the great chain of lakes, which may be included in the grand water-system of the river St. Lawrence. This great line or chain of connected lakes, comprises *Lakes Superior*, *Huron*, *Michigan*, *Erie*, and *Ontario*. "When viewed in connection with the river and gulf of St. Lawrence, by which their surplus waters are discharged into the Atlantic Ocean," observes Mr. Stevenson, "ideas of magnitude and wonder are excited in the mind, which it is impossible to describe. But the effects they produce on the commercial and domestic economy of the country, are considerations far more

important and striking. With the aid of some short lines of canal, formed to overcome the natural obstacles presented to navigation by the Falls of Niagara and the Rapids of the St. Lawrence, these great lakes are converted into a continuous line of water communication, penetrating upwards of 2000 miles into the remote regions of North America, and affording an outlet for the produce of a large portion of that continent, which, but for these valuable provisions of nature, must, in all probability, have remained for ever inaccessible."

Lake Superior, the largest of these vast sheets of fresh water, is, when measured in a somewhat curved line, about 380 miles in length; its extreme breadth amounts to 161 miles; and if its sinuosities be followed, its circumference is 1525 miles. Its average depth varies from 480 to 900 feet; but in some places, its depth is said not to be less than 1200 feet. There appears reason to infer that the waters of this, as well as of the other Canadian lakes, formerly occupied a much higher level than they reach at present; for, at a considerable distance from the shores, parallel lines of rolled (or water-worn) stones and shells, are seen rising one above another, like the seats of an ancient amphitheatre. The streams which pour their waters into Lake Superior, are several hundred in number, even without including those of smaller size, and the quantity supplied by these rivers, is many times greater than that carried off from the lake by the river of St. Mary, which forms its only outlet. The evaporation from this sheet of water must therefore be very great, as might indeed be anticipated, considering the vast extent of its surface.

The river St. Mary connects Lake Superior with *Lake Huron*. This lake is about 240 miles in length, and from 180 to 220 in breadth. The outline of Lake Huron is very irregular, and its shores are described as consisting of clay cliffs, rolled stones, abrupt rocks, and wooded steeps. This lake is crowded with islands, which render the navigation dangerous. *Lake Michigan* may be considered as an appendage of Lake Huron, with which it is connected by means of the navigable channel Michilîmackinac. Lake Michigan is about 300 miles in length, and 75 in breadth.

The connection of Lake Huron with Lake Erie is formed by the river St. Clair, which flows into a small lake bearing the same name; and from thence the river Detroit flows into Lake Erie. The whole of this connecting channel of the two larger lakes is navigable for vessels of all sizes, and the country on its borders, is described as a delightful tract, in which vegetation of all kinds, comes to greater perfection than in any other part of Canada. Lake Erie is about 230 miles in length, and its breadth varies from thirty to sixty miles. This lake is said to be the only one in the whole Canadian chain in which there is any perceptible current, a circumstance which is supposed to be attributable to its comparative shallowness; its average depth, according to a late survey, having been found to be not more than sixty or eighty feet. The current in Lake Erie, which runs always in one direction, combined with the great prevalence of westerly winds, and the occurrence of numerous sunken reefs and rocky banks, form serious obstacles to the safe and easy navigation of this lake, to which indeed steam boats are far more adapted than sailing vessels, and accordingly, have been introduced to a great extent. The shallowness of the water of Lake Erie likewise causes it to be more readily and more permanently affected by frost, so that its navigation is usually obstructed by ice for some weeks every winter, whilst that of the other lakes continues open and unimpeded.

The surface of Lake Erie is 330 feet above that of *Lake Ontario*, which is the most easterly of the chain, and that lying nearest the Atlantic. The surplus waters of Lake Erie are carried into Lake Ontario by the river Niagara. After the Niagara has flowed onwards for 16 miles, it suddenly precipitates itself over the rocky ledge which gives rise to the celebrated cataracts of that name. The river then passes for 7 miles through a deep rocky chasm, to Queenstown, where the limestone ridge terminates, and from thence through a level country for about 7 more, when it enters Lake Ontario. The length of Lake Ontario is about 172 miles and its breadth nearly 60 miles. Its depth is said to be very great, and it is navigable through-

out its whole extent for the largest ships of the line, and many splendid steamers are now employed in navigating its waters. In the years 1813 and 1814 this lake formed the theatre of all the great operations of war between the British and the United States. Owing to its great depth, Lake Ontario is rarely, if ever frozen over, though ice is formed at the sides where the water is more shallow, and in the year 1826, the ice at its margin was not less than two feet in thickness. The water of this lake is remarkably pure and clear; and it has been stated, that a white object, measuring a foot square, may be seen at the depth of 40 feet below the surface. The Canadian shores bordering on Lake Ontario are covered with majestic forests, and these tracts, when the noble trees fall beneath the axe of the settler, display an exuberantly rich and luxuriant soil, consisting of a deep mould of decayed vegetable matter, admirably adapted for agricultural and horticultural purposes.

The *lakes of Mexico* are of small extent, but are remarkable for their elevation above the sea-level, generally exceeding 7000 feet. These lakes are saline, a circumstance which may be attributed to the nature of the soil in which they are situated, which is strongly impregnated with saline matter.

The *Lake of Nicaragua* in Guatemala, or Central America, forms the most important hydrographical feature of that region. This lake is about 123 miles in length, and 60 in breadth, and it has in almost all parts a depth of 60 feet. It is connected by a navigable channel, 26 miles in length, with a smaller sheet of water, called the *Lake of St. Leon*, which may in fact almost be regarded as a branch of the lake of Nicaragua, and which is 50 miles long, and about 30 broad. Numerous affluents pour their waters into the lake of Nicaragua, but the river San Juan, which falls into the Gulf of Mexico, forms its only outlet.

It is in this portion of the New World that the waters of the two great oceans, the Atlantic and Pacific, most nearly approach each other, and it has been proposed to construct in this part, in connection with the Lake of Nicaragua, a grand oceanic canal, forming a navigable channel, and by this means

depressed only in Central America, apparently presents an insuperable obstacle to such a passage, excepting perhaps, in that particular locality, and possibly by means of the lake of Nicaragua. Whether the mighty work of connecting the two great oceans, by a navigable channel carried across this portion of America, and capable of admitting the passage of the largest sea-vessels, will ever be effected, remains to be proved; but it appears that, though on a very diminutive scale, a water communication between the Atlantic and the Pacific was actually opened so long since as the year 1788, by the spirited exertions of a single individual, not however, by means of the Lake of Nicaragua, but by a shorter route. In the interior of the province of Choco, (celebrated for its gold mines,) there exists the little valley or ravine of Raspadura, which lies between two small rivers, one of which is an affluent of the San Juan, and consequently flows into the Atlantic, and the other an affluent of the river Atrato, which enters the Pacific. At the above mentioned period, a very active priest, who was rector of the village of Novita, situated in that immediate locality, caused his flock to cut a small canal in the ravine of Raspadura; and this canal being supplied with water by the torrents which during the rainy season pour down into the ravine, is at that

period of the year navigable for small boats and canoes. This small canal has thus formed a connecting channel between the Atlantic and the Pacific; and after copious rains, small canoes laden with cacao have actually passed from the one ocean to the other, a distance, by this route, of little more than 50 miles.

CHAPTER XVIII.

THE OCEAN.

> Great Ocean, with its everlasting voice
> As in perpetual jubilee, proclaims
> The wonders of the Almighty ——SOUTHEY.

THE ocean forms the grand receptacle of all the surplus waters of the globe, the basin into which the greater number of rivers disembogue their liquid contents; the reservoir where they are held in store, ready to be again drawn off by the process of evaporation, when they are again required to perform their part in administering to the nourishment and refreshment of organized beings, or of effecting changes in the other departments of the physical world.

The area covered by the waters of the ocean is very great. In the present state of our knowledge, it is not possible precisely to determine its extent; but, as we have before seen, according to the nearest estimate that can be formed of the surface occupied by continents and islands, it is supposed that not less than three fourths of the globe are covered by the waters of the ocean. This difference in the relative amount of land and water is remarkable. But "who will venture to assert," observes Dr. Prout, "that the distribution of land and sea, as they now exist, though apparently so disproportionate, is not actually necessary, as the world is at present constituted. Let us conceive what would happen from the simple inversion of the quantities of dry land and sea as they now exist. In

such a case, there would not be enough of water to preserve the surface of the land in a moist state, and the greater part would be in the situation of the deserts of Africa, and totally unfitted for the habitation of human beings."

The ocean consists of one vast continuous fluid mass, which, owing to the perfect mobility of its parts among each other, and also to its natural gravity, flows into, and occupies the great depressions on the earth's surface, which constitute its bed, whilst the attraction of gravitation retains it in this its assigned position in the universe. The hydrostatic law of the equilibrium of fluids, moreover, causes this liquid mass to maintain a general level surface in all parts of the globe*, whatever may be the undulations of its bed. And thus it appears that, whilst the well adjusted distribution of land and water serves to maintain the globe in its present condition, the fundamental laws of nature retain the mighty ocean in the basin prepared for its reception. The earth is thus "covered by the deep as with a garment;" and this, being perpetually renewed, never perishes, never exhibits symptoms of decay; but apparently retains the same consistency, and possibly the same proportion as in "remotest eld."

No trace of time is left on thee,
Unchanging Sea!
Created thus, and still to be!

It will be evident that this vast body of waters, forming as it does, an enormous liquid mass, which preserves in all parts of the globe a general level surface, is in fact, one mighty whole, and that all divisions of the ocean are merely arbitrary. That they are of great utility in a geographical point of view, there can be no doubt, but in our present review of the world of waters, they need not engage our especial attention, particularly as we cannot but conclude, that our readers are

* The partial variations in the level of this vast body of waters, occasionally observable in deep gulfs, or inland seas, and arising from currents and other local causes, cannot be considered as forming exceptions to the general law of the level surface of the ocean.

already well acquainted with these nominal divisions of the ocean.

The depth of the ocean is a subject on which very little has hitherto been satisfactorily determined. That it varies greatly, there can be no question; for wherever its bed has been reached by the sounding line, it has presented inequalities similar to those occurring on the surface of the dry land. Its mean or average depth, is supposed not to exceed the mean height of the continents and islands above its level. Generally speaking, the greatest depths appear to occur in the broad sea, and the more shallow parts in channels and straits, or near islands. The mean depth of the sea round the coasts of England has been supposed not to exceed 120 feet; and on those of Scotland to be about 360 feet; whilst on the western coasts of Ireland it is considered to be about 2000 feet. In the North Atlantic Ocean, Mr. Scoresby sounded to the depth of 7200 feet, without the lead touching the ground; and in a recent expedition sent out by the French Government, soundings were made in the Austral or Southern Ocean, at the distance of about 300 miles from Cape Horn, when, although 2500 fathoms of line were let down, the lead did not reach the bottom. The hauling in of this line, although carried on by sixty sailors, lasted for more than two hours; and after making due allowance for the inclination of the line, it was supposed that the lead had descended 14,460 feet, without arriving at the floor of the ocean: and consequently, that the depth of the sea in that particular locality, must exceed that amount. There appears therefore reason to conclude that "if the sea were dried up, its bed would," to use the words of M. Arago, "present vast regions, mighty valleys, immense abysses, as much depressed below the general surface of the continents, as the principal summits of the Alps are elevated above its level." Experiments of this kind, even though conducted in the most skilful manner, cannot, however, be wholly depended on for the determination of great depths; because, since the pressure from the incumbent mass of waters becomes very great, the lead may be drawn out of the perpendicular direction, by cur-

rents, of which it may encounter more than one, flowing in different directions. So true it is that though

> Earth——her valleys and her mountains,
> Mortal man's behest obey·
> The unfathomable fountains
> Scoff his search, and scorn his sway.

The surface of the ocean being generally level, its waters are not subject to the same variations of *temperature* observable on land, where the temperature usually diminishes with the elevation above the sea-level. They appear, however, to be in some measure influenced in this respect by the irregularities of the bed on which they rest; for, generally speaking, the waters of the ocean are found to be colder where the water is shallow, than where it is of great depth. Thus, on approaching the shores of Ceylon, Dr. Davey observed a reduction of two degrees on coming into soundings; and, in a voyage made not many years since, from England to the Cape of Good Hope, the temperature of the surface water was observed to fall nine degrees at once, on the vessel's approaching within a few miles of the entrance of Table Bay. Until very lately, indeed, this change of temperature had been regarded as so decided an indication of shallow water, that it was supposed the mariner might rely on it as a means of discerning the vicinity of land, or of dangerous banks, or shoals, when traversing unknown seas. There appears, however, reason to conclude, that this is not absolutely to be depended on, as a warning of the approach of shallows: for M. Arago mentions, that when the French frigate Venus, approached the Archipelago of the Marquesas, in August, 1838, the pilot, half blinded by the dazzling reflection of the sun from the surface of the ocean, discovered, much too late for the apparent safety of the ship, a large shoal, situated near one of those islands. The course of the vessel could not be altered with sufficient speed, and she scudded over the borders of the reef, when she was shortly found to be in no more than six or eight fathoms of water whereas only a few hours before 200 fathoms of line had not

reached the bottom of the sea. And, notwithstanding this great variation in the depth of the ocean, from more than 1200 feet to only 36 feet, the water had maintained a uniform temperature of about 79° Fahrenheit. "This circumstance," observes M. Arago, "points out the caution with which generalizations of so important a nature should be regarded as established; at least in all cases; for, though under ordinary circumstances, it appears that shallow water is indicated by decreased temperature, yet certain conditions may occur, to cause a deviation from the general rule."

The temperature of the deep sea, appears generally to follow the mean temperature of the climate in which it is situated, but it is much less variable than that of the superincumbent air; and the latter is much less subject to variations, than air over the surface of land. Thus, in equatorial regions, the difference in the temperature of the air near the surface of the sea, by day and night, does not appear to exceed three or four degrees; whilst on land it amounts to nine or ten degrees. And though the diurnal range of temperature near the surface of the ocean, is rather greater in temperate climates, it is by no means equal to that on land. Thus, in the parallel of Paris, the range of the thermometer, in the air over the ocean's surface, amounts only to five or six degrees, whilst at Paris it often amounts to thirty or forty degrees.

In warm climates, the temperature of the deep sea diminishes with the depth below the surface. Thus, Captain Sabine mentions that, according to some experiments made in the Caribbean Sea, the temperature at the surface was 83°, and only 45° at the depth of 1000 fathoms. This decrease of temperature is, however, apparently so dependent on various conditions, that in the present state of our knowledge, there appears no reason to conclude, that it follows any uniform law. For, it is sometimes found that a decrease of one degree occurs at the depth of five fathoms, whilst in other instances, a similar decrease occurs only at the depth of 100 fathoms. The maximum, or greatest degree of cold, again, sometimes occurs at a depth of 100 fathoms, and sometimes at that of 400 or 500

fathoms. In temperate climates, where the surface of the sea is less warm, the *decrease* on descending is not so great; because it appears that the temperature of deep water is rarely lower than 40° Fahrenheit. The latter temperature had indeed long been considered as the maximum degree of cold attained by the deep ocean, but according to some recent observations, made on board the French frigate Venus, the temperature in some particular localities, both in temperate and intertropical regions, has been found as low as 37°, 36°, and even 35° Fahrenheit; and this at some places, where the thermometer at the surface stood at 79° and 80°. This greater degree of cold is however supposed to be attributable to submarine currents of cold water.

At about 70° north latitude, a zone exists, at which the mean temperature of the ocean is considered to be similar at all depths. In the Polar seas on the other hand, the temperature is found to *augment* with the depth; though the rate of increase of temperature, like that of the decrease in warmer latitudes, does not appear to be referrible to any fixed law, but to vary in different localities. Thus, Mr. Scoresby found an increase of six degrees and a half at the depth of 120 fathoms, whilst Captain Parry found that the increase of temperature at the depth of 240 fathoms did not exceed six degrees: and again, on another occasion, Mr. Scoresby observed an increase of only eight degrees, at the depth of 730 fathoms, whilst Captain Beechey found an increase of ten degrees at that of 700 fathoms.

The waters of the ocean are, as is well known, not pure, but hold in solution a variety of saline matter, amongst which by far the most abundant is chloride of sodium, or common salt, which in general constitutes above two thirds of the whole saline ingredients. Thus according to a recent analysis made by Dr. Schweitzer, 1000 grains of sea water taken from the British Channel, near Brighton, contained twenty-seven grains of chloride of sodium, and not much more than eight grains of other saline matter; the whole *anhydrous*, (or *not-watery*)

ingredients, amounting to rather more than thirty-five grains, in the 1000 grains of sea-water. The specific gravity at 60° Fahrenheit, (pure water being 1.000,) was 1.027. The quantity of saline ingredients contained in sea-water, is however found to vary in different localities. Thus, according to Lenz, who accompanied Kotzebue in his voyage round the world, the Atlantic Ocean is salter than the Southern Ocean. In the Atlantic Ocean, again, the western portion has been found to be more salt than the eastern; whilst no variation in the saltness of the water has been observed in any part of the Pacific Ocean. It appears, however, a general rule, that in high northern and southern latitudes, the quantity of saline ingredients is less than in warmer latitudes; probably owing to the greater amount of evaporation in the latter localities. A series of interesting experiments were made on this subject by the late Dr. Marcet, who procured for this purpose above seventy specimens of sea-water, from different parts of the world, some of which were raised from great depths. From these observations, Dr. Marcet came to the conclusion, that the sea is not salter at greater depths than near the surface; but that it generally contains more saline matter, where the water is deepest and most remote from land, probably owing to its not being subject to the influx of fresh water carried down into it by the rivers which enter the ocean.

The saltness of the ocean is likewise diminished in the vicinity of large masses of ice. Branch or inland seas, especially those occurring in high latitudes, are much less salt than the ocean; their inferior saltness being usually attributable to the streams of fresh water which flow into their basin, whether from the drainage of the adjacent coasts, or in the form of rivers of considerable size. Such is the case with the Baltic Sea, which, besides the drainage from the surrounding land, receives numerous important streams, amongst which is the river Neva, the outlet of the surplus waters of the great Russian lakes; and the waters of that sea accordingly are found to contain a very small proportion of saline matter, and their specific gravity does not exceed 1.015.

The Mediterranean Sea, however, forms an exception to the general rule of the inferior saltness of branch or inland seas; the waters of that sea being found to contain rather a larger proportion of saline matter, than those of the main ocean. Though, perhaps, in part attributable to the warmth of the climate, and the consequent rapid evaporation, this circumstance alone does not appear sufficient to account for the difference; which is therefore supposed to be due in great measure to the peculiar situation of this branch of the ocean, bordered, as it is, on the south by the arid and burning shores of Africa, and thus exposed to the powerful radiation from those sandy plains, and to the parching winds which blow over the adjacent desert tracts, and which, crossing this sea, cause an unusual amount of evaporation from its surface. It thus would appear that the rivers which flow into its basin, do not furnish it with a sufficient quantity of fresh water to replace the amount carried off by this means. The consequence of this is, that to maintain its level, a current always sets in from the Atlantic, and thus the Mediterranean Sea is continually receiving supplies of salt water, and as the process of evaporation proceeds, the water becomes salter than that of the ocean. According to this supposition, however, this sea would gradually increase in saltness, until at length it would be converted into brine. To explain away this difficulty, it is supposed that an under current, of salter, and consequently denser water, flows out at the Straits of Gibraltar, thus carrying off the excess of salt from these waters into the Atlantic Ocean. In order to verify this hypothesis, the late Dr. Wollaston procured specimens of the water from this immediate locality, at the depth of 670 fathoms, when it was found to contain four times the usual quantity of saline ingredients.

The saline contents of the ocean are of very great importance in the economy of nature. The purer water is, the more rapidly does it pass off in vapour; and it may be questioned whether, if the ocean were composed of fresh water, the mass of waters could be maintained in its present condition, owing to the greater rapidity with which the process of evaporation

would be carried on. And thus, as has been well observed by Dr. Prout, "there is reason to believe that the saline matter contained in the ocean contributes in no small degree to the stability of the water; and that an ocean of fresh water would undergo changes which would probably render it incompatible with animal life. The waters of such an ocean might even be decomposed, so as seriously to interfere with the other arrangements of nature."

We have seen that the saline matter contained in sea water affects its specific gravity: this also is not without its utility, both in the economy of nature, and also to man. In illustration of its importance in the natural world, we may remark, that the greater degree of buoyancy thus acquired by the water, enables it to bear substances on or near its surface, which in fresh water would probably sink to the bottom. And it is by this means that hard seeds, such as those of the cocoa-nut and pandanus, are borne to the newly-formed coral islands of the Pacific Ocean, there to perform the important office, of colonizing these islands with valuable vegetable productions; and thus adapting them for the habitation of man. It is also owing to the same greater degree of buoyancy possessed by the waters of the ocean, that they are better fitted for the purposes of navigation, on account of their specific gravity being thus greater, in proportion to that of the materials used in the construction of ships.

The saline contents of the sea water of the British Channel, according to Dr. Schweitzer, consist of:—

	Grains.
Water	964.744
Chloride of Sodium	27.060
Chloride of Potassium	0.765
Chloride of Magnesia	3.667
Bromide of Magnesia	0.030
Sulphate of Magnesia	2.295
Sulphate of Lime	1.406
Carbonate of Lime	0.033
	1000.000

Dr. Schweitzer also found a trace of iodine in the sea water; but the quantity was very minute, 174 lbs. troy weight not containing one grain. "This," he observes, "is very remarkable, when we consider the comparatively large quantity of iodine and bromine present in sea plants and animals; hence we must conclude that these principles are concentrated by vital action*."

The freezing point of water is also affected by its saline contents. The freezing point of fresh water is (as is well known) 32° Fahrenheit; that of sea water is 28° or 29°. The waters of the ocean, therefore, require a greater degree of cold than those of a fresh water lake, to convert them into ice. From this circumstance, and from the great depth and extent of the ocean, its waters resist freezing more effectually than even running water; and are therefore rarely covered with ice, except in latitudes where the cold is exceedingly intense, and of very long duration. The beneficial results accruing from this natural arrangement are, that the surface of the ocean, that important "highway of nations," is less liable to be encumbered with ice, and the traffic on its waters to be impeded, than would have occurred had other conditions prevailed.

We thus find that it is only in very high latitudes that ice is formed in the open sea. Detached masses of ice, or floating icebergs, are, however, occasionally met with in much lower parallels of latitude: the extreme limit at which they have been observed in the northern hemisphere, being in the parallel of 40°; whilst in the southern hemisphere they have been met with at different points off the Cape of Good Hope, between south latitude 39° and 36°. One of the latter, which was two miles in circumference, and 150 feet in height, is described as having presented the appearance of white chalk, when the sun was obscured, and as having the lustre of

* Some conception may be formed of the pervading influence of the principle of iodine, when we learn that Dr. Schweitzer ascertained, from experiment, that "a minute quantity of iodine in distilled water, equal to no more than 1,500,000th part of the whole, will be distinctly indicated by a decided pink hue, when mixed with starch, dilute sulphuric acid, and chlorine."

refined loaf sugar when the sun was shining on it. Others of these masses rose from 250 to 300 feet above the level of the sea, and must therefore have been of great volume below the surface; it having been ascertained, by experiments made on the buoyancy of ice floating on sea water, that for every solid foot seen above, there must be at least eight cubic feet below water.

We have seen that the lowest limit at which icebergs have been observed in the northern hemisphere, is the parallel of 40°; but it will be readily seen that they cannot have been formed in that latitude, having in fact been borne from the icy region of their birth, by currents setting southwards from the Polar seas. In north latitude 50°, however, the shallow edges of the sea are in many parts covered with ice during the winter; and in the parallel of 60°, we find that the gulfs and inland seas frequently have their whole surface frozen over. Proceeding towards the North Pole, we find the ice becoming more and more abundant, until at length the sea is so covered with fields and mountains of ice, that the navigator is checked in his onward course.

The process of congelation commences at the surface of the sea, with the formation of slender prismatic crystals, resembling wet snow; this the seamen call *sludge*. The surface is at first rough; but by the union of the crystals, and the accumulation of the *sludge*, the surface becomes smooth, and forms a continued sheet of ice, which, however, ere long is broken by the agitation of the water, into fragments of three or four inches in diameter. These fragments usually again coalesce into a sheet of ice of stronger texture than the preceding, but not sufficiently firm to withstand the action of the waves, and which, therefore, in its turn is broken into fragments, generally of larger size, and called by the seamen *pancake ice*. When these again become united, and the ice attains the thickness of two or three inches, it is termed *bay ice;* when the thickness is about a foot, it is called *light ice;* and when three feet in thickness, it is distinguished as *heavy ice*. Large loosened masses or sheets of floating ice, whose boundaries may be readily

descried, are called *ice floes;* and the term *ice field* is applied to a sheet of ice so extensive, that its boundaries cannot be seen from a mast-head. To form such a sheet of ice, a long continuance of very severe cold is of course required; but, during twenty-four hours of keen frost, the ice frequently attains a thickness of two or three inches, thus forming what is termed *bay ice.* When the water is free from agitation, congelation proceeds with less interruption, and ice fields are more rapidly formed; but so great is the severity of the frost in these regions, that the raging billows have not power to arrest its progress; and on one occasion, when Sir Edward Parry was sailing in the Arctic Ocean, the cold was so intense that, notwithstanding the waters were agitated by a hard gale, ice was continually formed in the sea.

Icebergs, or ice mountains, are sometimes formed in the sea itself by the accumulation of ice and snow; but more frequently, perhaps, consist of glaciers which have been formed on the shores, and which being undermined by the sea, or intersected by the melting snow flowing through their crevices, become detached, and falling into the water, are floated out to sea. Icebergs are particularly abundant in north latitude 69° or 70°; and they are very numerous in Baffin's Bay, where they are sometimes met with two miles in length, and nearly half that width. They are also of frequent occurrence in Hudson's Bay. The Rev. Mr. West mentions that in his passage through Hudson's Straits, "the progress of the vessel was impeded by vast fields of ice and icebergs floating past it in every form of desolate magnificence. The scene," he observes, "was truly grand and impressive, and mocks imagination to describe. There is a solemn and an overwhelming sensation produced in the mind by these enormous masses of snow," continues Mr. West, "not to be conveyed in words. They floated by us, from 100 to 200 feet above the water, and sometimes of great length, resembling high mountains with deep valleys between lofty cliffs, and all the imposing objects in nature, passing in silent grandeur, except at intervals, when the fall of one was heard,

or the crushing of the ice struck upon the ear like the noise of distant thunder."

An ice-field, when in motion, coming in contact with another moving in a contrary direction, produces a dreadful shock. Let the reader picture to himself a body of more than ten thousand million of tons in weight meeting with a similar body in motion! "No description," says Sir John Ross, "can convey an idea of a scene of this nature; and as to the pencil, it cannot represent motion, or noise. And to those who have not seen a northern ocean in winter—who have not seen it, I should say, in a winter's storm—the term ice, exciting but the recollection of what they know only at rest, in an inland lake or canal, conveys no idea of what it is the fate of an Arctic navigator to witness and to feel. But let them remember that ice is a stone,—a floating rock when in the stream, a promontory or an island when aground,—not less solid than if it were a land of granite. Then let them imagine, if they can, these mountains of crystal hurled through a narrow strait by a rapid tide; meeting, as mountains in motion would meet, with the noise of thunder; breaking from each other's precipices huge fragments, or rending each other asunder, till, losing their former equilibrium, they fall over headlong, lifting the sea around in breakers, and whirling it in eddies; whilst the flatter fields of ice forced against these masses, or against the rocks, by the wind and the stream, rise out of the sea till they fall back on themselves, adding to the indescribable commotion and noise which attend these occurrences." So violent, indeed, are these concussions, that as Captain Scoresby says, "the strongest ship can no more withstand the contact of two ice-fields than a sheet of paper can stop a musket-ball."

On the frozen deep's repose
'Tis a dark and dreadful hour,
When round the ship the ice-fields close,
To chain her with their power!

"Such is the ice:" and yet, as Sir John Ross further has observed, "it is far from being an unmixed evil; and estimating all our adventures with and among it, I might not be

wrong in saying, that it had been much oftener our friend than our enemy. We could not, indeed, command the icebergs to tow us along, to arrange themselves about us so as to give us smooth water in the midst of a raging sea; nor, when we were in want of a harbour, to come to our assistance, and surround us with piers of crystal, executing in a few minutes works as effectual as the breakwaters of Plymouth or Cherbourg; but they were commanded by Him who commands all things; and they obeyed."

The point of congelation of sea water, as we have seen, is lower than that of fresh water; but it appears that sea water parts with its salt in freezing; and hence, compact transparent ice, formed of sea water, affords nearly fresh water on being melted; a circumstance of immense importance to the arctic navigator. Being, however, devoid of air, it does not form either a pleasant or quite wholesome beverage, unless aërated before use. When sea ice is not compact, the interstices not unfrequently contain brine; and if therefore the whole mass be dissolved, the water will be brackish, and unfit to drink.

The taste of sea water is disagreeable, being both salt and bitter, and it is unfit either for culinary purposes, or as a beverage for man, at least in his civilized state; for it is said that it is used for that purpose by the inhabitants of Easter Island, in the Pacific. Some animals are observed occasionally to travel far to drink sea water; but this would appear rather to be as a restorative, than for an ordinary beverage; animals being also observed to frequent sulphureous springs, apparently for similar purposes.

Sea water appears to be very transparent when undisturbed by extraneous causes. In general, it is more transparent as we recede from the shore, and also in cold climates than in hot. To this there are, however, some exceptions; for the water immediately off the Virgin Islands, in the Caribbean Sea, is so remarkably clear, that at the depth of eight or nine fathoms, the floor of the ocean is quite discernible, and the sea-sponge may be distinctly seen in its natural bed.

The changing colours of the sea are familiar to all who have visited the shores of the mighty deep:—

> In colour changing, when from clouds or sun,
> Shades after shades upon the surface run;
> Embrowned and fearful now; and now serene,
> In limpid blue, or evanescent green.

These almost perpetually varying hues displayed at the surface of the ocean, owe their existence in great measure to the mere reflection of the changing skies in the water. Thus, for instance, an apparently dark inky-coloured sea is usually indicative of an approaching storm; not, however, because the water is really blacker than usual, but because it reflects the general hue of the atmosphere near the horizon. In some cases, however, these hues are attributable to local causes; for the greenish tint which usually occurs in shallow water, appears to be owing to the yellowish sands in the bed of the ocean, which, mingling its hues with the blue tints of the latter, impart this hue to the whole mass. But what, then, it may be asked, is the real colour of the ocean? The various particulars connected with this subject, which have been collated by M. Arago, will form the best reply to this inquiry. "Mr. Scoresby (he observes) compares the general tint of the Polar Seas to the blue of *ultramarine*. M. Cortez considers the waters of the Mediterranean to resemble a perfectly clear solution of the finest *indigo;* he also describes them as of a *bright sky blue*. Captain Tuckey characterizes the waters of the Atlantic Ocean by the term *bright azure*. It would therefore appear that the colour of the ocean, when its waters are unmixed with foreign matter, may be considered as sky-blue, of greater or less intensity, according to the proportions of reflected light." The ocean, however, does not present this sky-blue colour in all localities, this tint being sometimes modified, or even totally changed, in situations where the water has little depth; this variation being dependent on the nature of the bed of the sea. Thus, as has just been observed, a bed of yellow-coloured sand imparts to the sea a greenish tint, because the combination of yellow and blue form that colour; and the brilliancy of the green will of course

depend on the brightness of the sand. If the bed of the sea be red, the tint of the waters may be either purplish or red. Thus, the waters of the Mediterranean Sea in some parts occasionally appear of a purple hue; possibly owing to the red coral which occurs in its bed, combined with the bright sky-blue water. In the Bay of Loango, off the western coast of Africa, the waters always present the appearance of being so strongly tinged with red, that they might be supposed to be mixed with blood. Captain Tuckey, however, satisfied himself, that the appearance arose from the intensely red colour of the bed of the ocean in that bay.

The reflection of different hues from the bottom of the sea, is not, however, the sole cause of the various colours observed in some parts of the ocean; for it appears that, in many instances, this arises from the presence of innumerable living creatures of minute size. Thus, in the Polar Seas, strongly-marked bands, or stripes, of green-coloured water occur, the tint of which is due to the presence of myriads of semi-transparent medusæ of a yellowish colour, and which, when blended with the blue colour of the ocean, produce this green tint. The colour of the sea, where these medusæ do not occur, is, as has just been mentioned, of an ultra-marine blue, and beautifully transparent; the green water, on the contrary, has a great degree of opacity. When the medusæ are very abundant, the water is described by Mr. Scoresby as of nearly a grass-green colour, with a shade of black. The number of the medusæ in the green water was found to be immense; Mr. Scoresby having calculated that a cubic foot of water would contain 110,592 individuals. It is in this olive-green water that the northern clio, which forms the principal food of the whale, is chiefly found; it is therefore supposed that the medusæ are preyed on by the clio, itself destined to become the prey of the whale. And here accordingly, does the great enemy of the latter,—the whale-fisher,—seek for his prize; and thus, the whale, whilst pursuing his prey, falls a prey to the rapacity of man.

In other parts, the ocean is of a brown colour, which also

appears to be due to the presence of innumerable minute animals; and to a similar cause is attributable the milky-white hue which prevails in some localities. The latter was observed in a remarkable degree by Captain Tuckey, off Cape Palmas, on the coast of Guinea, where the vessel appeared to float in milk. On examining the water, this white appearance was found to proceed from multitudes of minute animals floating on the surface, which concealed the natural hue of the water. Off the coast of Brazil, the waters of the sea have been observed to present a deep red hue, which is supposed to arise from the occurrence of minute molluscous animals, which float in countless myriads in that part of the ocean; and it is more than probable, that the Vermillion Sea, near California, has derived its name from a similar cause.

The *phosphorescence*, or *luminosity* of the ocean, is by no means an uncommon, though a very remarkable phenomenon. The luminous appearances thus exhibited on the surface of the sea are very varied. Sometimes a vessel, whilst traversing the ocean, seems to mark out a track of fire, and (if oars be used) each stroke of the oar causes the emission of light, sometimes brilliant and sparkling, and sometimes tranquil and pearly. Sometimes, again, innumerable points glitter over the whole surface of the ocean, whilst at other times, a broad sheet of light extends in all directions; and this, perhaps, may then suddenly break up into a thousand parts, in which an active imagination may conjure up every form and figure. Different causes have been assigned for this phenomenon; but it would appear, that although it in all probability occasionally originates in the phosphorescence of decaying organized substances, diffused in the waters of the sea, yet the most usual cause of the luminosity of the ocean is the presence of vast numbers of living creatures, which possess the power of emitting light.

With regard to the former class of luminous appearances,—that produced by the phosphorescence of decaying organized substances,—it is well known that rotten wood, some kinds of peat-earth, and also various animal substances, soon after they are deprived of life, possess the power of emitting spontaneous

light. Such appears to be the case, more especially with most marine fishes; and, according to a series of experiments made some years since by Dr. Hulme, chiefly with herrings and mackerel, it seems that these fish not only exhibit this lucid appearance themselves, shortly after life is extinct, but that they have the power of imparting it to certain solutions in which they may be immersed, and that these solutions actually retain this power of emitting spontaneous light for some time. Thus, Dr. Hulme found that solutions of sea salt, of Epsom salt, &c., when impregnated with some of the lucific matter scraped from herrings and mackerel, retained the light for several days, which was more especially exhibited when the phial in which they were contained was agitated. The phenomena thus displayed are described by Dr. Hulme as not less surprising than beautiful; for he was enabled to take light from one substance and transfer it to another, so as to render the latter most brilliantly luminous. This luminous matter was obtained in greatest abundance from fish, shortly after life had become extinct, and before putrefaction had commenced. These interesting experiments might lead us to conclude, that in some instances, the luminous appearances exhibited on the surface of the ocean, may arise from the light emitted by marine fishes after life has become extinct, and which is probably removed by friction from the decaying body of the animal, either by the action of a vessel passing through the water, or that of an oar, (to which it may occasionally adhere,) or else by the agitation of the waves, which thus becoming impregnated with this luminous matter, appear luminous themselves.

The second class of luminous appearances on the surface of the ocean, namely, that produced by living animals, is a yet more remarkable phenomenon than the preceding. The power of emitting spontaneous light appears to be possessed by several inhabitants of the ocean, among which we meet with some crustaceous animals, though the greater number belong to the radiated animals. The most remarkable of the former is the *cancer fulgens,* which in some degree resembles a shrimp in form. The whole body of this creature sometimes appears

illuminated, emitting very brilliant scintillations of white light. It is to the *cancer fulgens*, and other nearly similar species of crustaceous animals, that, as we have just seen, Captain Tuckey attributed the white hue of the sea in the Gulf of Guinea. One species, however, when examined in the microscope, presented rather different phenomena from those above described, for the luminous property appeared to be confined to the head of the animal; the luminous point, when the little creature was at rest, resembled a most brilliant amethyst, but when it moved, flashes of bright silvery light darted from this spot. Among the other luminous inhabitants of the ocean, are the *beroe fulgens*, the *medusa pellucens*, the *pyrosoma atlantica*, &c. The *beroe fulgens* is about an inch in length, and of a cylindrical form. In some parts of the ocean, this animal is met with in myriads, of every hue and shade, from the deep green of the emerald, to the purple of the amethyst. The *medusa pellucens* is about five inches in diameter, and the flashes of light proceeding from it are said to be so vivid, that they dazzle the eye of the spectator. The *pyrosoma atlantica* is of a cylindrical form, and appears destitute of any organs, with the exception of a very delicate structure resembling net-work, which extends over the interior of the cylinder. The general hue of the light emitted by the pyrosoma appears to be red; but Peron, who first observed it, speaks of it as assuming a great variety of tints, pink, orange, green, and azure blue.

Such being some of the phenomena presented by the various bodies, whether living, or after life is extinct, to which the luminosity of the ocean seems to be attributable, it will be readily supposed, that where these creatures occur in great abundance, the appearances they exhibit are sometimes very imposing and splendid. The phenomenon is displayed in greater lustre in warm climates, but is by no means confined to those regions, being frequently witnessed off our own shores; and Professor Trail mentions that he met with luminous animals belonging to the genera medusa and beroe, in the North Atlantic Ocean, between the thirty-seventh and sixtieth

parallels of latitude; and on one occasion, so brilliant was the luminous appearance of the ocean, that the professor could, by this light, distinguish letters in a book, and also discern the hour on a watch, although in other situations on the deck of the vessel, it was so dark, that the features of the seamen could not be distinguished. When the hand was immersed in the luminous water, the shining particles were found adhering to the fingers, and the water was almost invariably observed to contain animals of the genera medusa and beroe.

M. De Tessan observed in False Bay, at the Cape of Good Hope, a remarkable instance of this phenomenon, which appeared to be due to the presence of an innumerable quantity of small, hard, spherical bodies, which were in such abundance, that the water was quite thickened by them. On agitating the water with the hand, a slight crackling sound was heard, as when snow is pressed. Some of this water, when strained through a cloth, left half its bulk of these minute creatures. The water which had been strained had lost its luminous properties, but the remaining animal matter possessed it in a high degree. Dr. Buchanan, speaking of this phenomenon as witnessed off the coast of Africa, states that "soon after dark in the evening, it being nearly calm, we saw numerous lights at a distance, like the lamps of a great city. The lights gradually approached the frigate, and on reaching us, appeared to arise from the circumstance of a great many large fishes in the water, which agitated the animalcules, so as to excite their luminous powers." Mr. Bennett's observations led him to the conclusion that there are two kinds of luminous appearances presented at the surface of the ocean, the one being produced by various species of medusæ, whilst the other exhibits no indication of the presence of living animals, and which, therefore, may be considered as originating in light emitted from the bodies of decaying marine animals. He observed that the former usually presented the appearance of sheets or trains of whitish or greenish light, often sufficiently brilliant to illuminate the vessel as it passed through the water; whilst in the latter instance, the surface of the sea appeared studded with scin-

tillations of light of the most vivid description, more particularly when the waves were broken by the violence of the wind, or by the passage of the vessel through the water. Sometimes within the tropics during heavy rains, Mr. Bennett observed that the sea would suddenly become luminous, and the light would as suddenly pass off again; the effect of these rapid transitions being exceedingly splendid and striking to the beholders.

The waters of the ocean are in perpetual movement, from the effects of the *tides*, as well as of winds and currents. The *celestial mechanism* of the tides, or the solar and lunar attraction by which the original impulse is given to the tides, does not belong to our present inquiry; but a brief notice of the mode in which the mass of waters, when thus set in motion, is transferred from one place to another, forms a portion of the natural history of the ocean. It appears from the recent researches of Mr. Russell, that the attraction of the heavenly bodies raises the vast mass of the waters of the ocean to a certain elevation, thus forming one mighty wave, designated as the *great primary wave.* The waters being thus raised above their ordinary level, are immediately impelled, by their natural gravity, again to return to their wonted level, and the velocity with which this is effected will be dependent on the height to which the mass of waters has been raised. This moving mass of water, in obedience to the laws of hydrostatic equilibrium, spreads in every possible direction, extending round from the spot of its original elevation, without oscillating or retrograding, and not only moving onwards itself, but imparting motion to every particle of the water through which it passes. It is to the arrival on our shores of this grand primary wave, that the phenomenon of *high water*, or *flood tide*, is due; and when the vast mass of waters is drawn to its elevation in the open ocean, the water recedes from the shores, and it is then *low water*, or what is called *ebb tide*. This mighty tidal wave does not, however, reach our shores until 50 or 60 hours after its formation, having in the interval moved in

every possible direction, and with a velocity varying from 10 to 100 miles an hour.

The height of the tides at particular places, is, however, dependent on local causes, and mainly, on the configuration of the land. Thus, in deep bays or inlets, especially when contracted like a funnel, the convergence of the water causes a great increase of the range between high and low water. Thus, at Chepstow, the tide rises from 45 to 60 feet; and in the Bristol Channel, the tide has been known to rise 70 feet; but its ordinary rise is 33 feet. In the Thames at the London Docks the average range is about 22 feet; at Portsmouth and Plymouth 12 feet 6 inches.

The waves of the sea which are caused by the action of the wind,are of a totally different character from the great tidal wave, and have been denominated *secondary waves*. There is generally much appearance of confusion in an agitated sea, for the waves do not seem to be regular, either in their forms, their intervals, or their velocities; but those who have closely observed the phenomena of waves, inform us, that in this, as well as in most of nature's performances, method exists even in apparent irregularity. The wind is continually in a greater or less degree, shifting its point; and every breeze that ripples the surface of the waters, gives rise to a series of waves, which move in the direction of that breeze. And as breeze succeeds to breeze, each perhaps blowing from a slightly different point, and forming fresh series of waves before the former have subsided, the waves cross and intersect each other, thus, to the unpractised eye, presenting the appearance of a chaos of troubled waters; though by a little patient attention to the phenomena, much of this seeming confusion may be dispelled. The largest waves of this class are produced by sudden changes of wind; and the ocean is comparatively smooth, in regions where the winds are constant, or invariable. Since it is by the friction of the winds, that the waves of the sea are raised and kept up, whatever diminishes this friction, will tend to lessen their height; and hence, comparative tranquillity is produced by pouring oil on

agitated water. The following remarkable account of the stilling of an agitated sea in an analagous manner, is given by Daniel Wheeler, a member of the Society of Friends, who visited the Sandwich Islands a few years since. "The sea was running in mountainous succession, and some of the loftiest waves were nearly prevailing against the little vessel. At this critical moment, a collection of a small species of whale, perhaps more than 200 in number, was observed close to the ship. They served as a breakwater to the little struggling vessel; they occupied a considerable portion of the surface of the sea, in the exact direction between the vessel and the wind and waves, reaching so near us, that some of them might have been struck with a harpoon. They swam constantly in steady order, as if to maintain a regular phalanx. Not one sea broke on board whilst they occupied their useful post."

The influence of the wind, being exerted entirely at the surface, does not extend to any great depth; probably not more than thirty or forty feet, below which the water suffers no agitation, excepting that which arises from the grand tidal wave, and, probably, in some parts of the ocean, from submarine currents.

> The water is calm and still below,
> For the winds and the waves are absent there;
> And the sands are as bright as the stars that glow,
> In the motionless fields of the upper air.

When waves of the class we are now considering, approach the shore, or pass over rocks or shoals, they break when they reach the point where the depth of the water, is nearly equal to the height of the wave above the general level of the water. When at a distance from the shore, waves are comparatively long and low, but as they approach the shallow part of the coast, they assume a greater curvature; and hence the depth of the water may be judged of, by the height and form of the waves. Where a wave of five feet, for instance, can exist, the water will have a depth of at least five feet; and wherever breakers are formed on a calm day, there the depth of the water may be considered as being equal to the height of the waves above its surface. The utmost elevation of a natural wave

according to some authors, does not exceed twelve feet; but others estimate the utmost limit at twenty feet; and under some circumstances, waves reach a much greater height.

The heavy swell which occasionally takes place in the northern coasts of some of the West India Islands, and which is locally termed the *ground sea*, presents some remarkable features. The sea, although the air is calm, and there has been no indication whatever of a previous gale, rises, rages violently, and then subsides.

> The sea
> Did rise and fall, and then that fearful swell
> Came suddenly, which seamen know so well.

A heavy ground sea is described as a grand and sublime phenomenon. The sea approaches in undulating masses, which usually rise suddenly into large ridges, crested with foam, and form billows which burst upon the beach with the greatest impetuosity, attended with loud roarings resembling thunder; the spray being thrown up to the height of more than 100 feet. Wave follows wave, in quick succession, a short interval, however, apparently occurring after every third wave. The sea, for many miles from shore, assumes a peculiar aspect, and its various tints of blue, from the darkest to the lightest shades, form a striking contrast with the snow-white foam of the breakers, when they dash against a hidden rock, or burst upon the shore. The north-eastern coast of Jamaica, St. Domingo, and the Bahamas, are subject to the ground sea, but it is of most frequent occurrence at Puerto Rico and the Virgin Islands. This phenomenon is supposed to be caused by distant gales in the Atlantic, which agitate and as it were push forward the water in this particular direction, but which do not themselves extend to this region.

Another phenomenon exhibited at the surface of the ocean, is that known by the name of *ripples*. This agitation of the sea, is the more remarkable, from its occurring in situations where there are no soundings. This phenomenon was witnessed in the year 1814, by his Majesty's ship Minden, when at some distance from the island of Sumatra; no land, however,

being in sight. In this instance, although the weather was calm, and the water of great depth, "the sea was agitated with uncommon fury. Some of the ripples were heard several miles off, and advanced towards the ship, boiling and foaming in an extraordinary manner. The more violent ones actually shook the ship in a considerable degree. Their effect during the night, was prodigious and alarming: at first, a low hollow sound was heard, like that caused by surf on a distant coast; it gradually became louder and louder,—until at length a long foaming streak was discovered, advancing rapidly towards the ship, which it soon surrounded, and all was noise and commotion. This lasted for a few minutes, when the ripples moved to the north-east: its sound became fainter and fainter, and it often happened that, just as one ceased to be heard, another was perceived; and so on, during the night." The cause of this remarkable agitation of the sea, does not seem to be well understood; but it has been supposed to originate either in the meeting of waves from different oceans, or of currents of wind opposing each other; though neither of these hypotheses offer a satisfactory explanation of the phenomenon.

Currents in the ocean arise from various causes, either occasional, or constant. They may be caused by a gale of wind; by a difference of temperature in different parts of the ocean; by the melting of the Polar ice; or by any other cause tending to disturb the hydrostatic equilibrium. Among those which possess a permanent character, there are two very remarkable currents, both of which are chiefly caused by the diurnal rotation of the earth; the first being produced by the perpetual movement of the waters from the polar regions to the equator; and the second, by the progression of the tropical seas towards the equator. In accordance with the laws of mechanics, an accumulation of water takes place, in that part of the globe which has the greatest velocity of motion, that is, in the equatorial regions; the consequence of which is, that the waters flow from the polar regions towards the equator, and thus currents are formed, which continually move in that direction,

constituting the *polar currents*. The second great current—that of the progression of the tropical seas in a westerly direction—is partly caused by the trade winds, which blow continually from east to west, and partly by the mobility of the particles of water; for, with regard to the latter, we find, that when the water brought by the polar currents arrives in the equatorial regions, the fluid mass does not immediately acquire the degree of velocity possessed by the solid land: and, since the rotation of the earth is from west to east, the water not moving with equal velocity, has an apparent motion from east to west, that is to say, apparent, as far as regards the mass of the globe, but real, as regards the adjoining land and waters. This *equatorial current* becomes very evident both in the Atlantic and Pacific Oceans, between the parallels of 30° on each side of the equator. It has an average velocity of nine or ten miles per day in the open sea.

An extensive system of currents appears to originate in the Indian Ocean. A current first passes through the Mozambique Channel, and, under the name of the Aiguillas current, sweeps round the Cape of Good Hope in a powerful stream, running at the rate of from two and a half to four miles an hour, and having a breadth of about 100 miles. From the Cape, it flows along the western coast of Africa, under the name of the *South Atlantic Current*. It then enters the Bight, or Bay of Benin, from whence it is deflected, and unites itself with the equatorial current. Having thus traversed the Atlantic from the coast of Guinea to that of Brazil, it divides into two branches, this division being apparently caused by the jutting form of South America, at Cape St. Roque. The southerly branch flows along the eastern coast of South America, and passing through the Straits of Magelhaens, enters the Pacific Ocean. The northerly branch skirts the shores of Brazil and Guiana, where it is increased by the influx of the waters of the Amazonas and the Orinoco, acquiring accelerated velocity by the vast volume of water they pour into the ocean. After passing the island of Trinidad, this "oceanic river" expands, and enters the Gulf of Mexico. The current sweeping round that

inland sea, pours forth from thence, forming the most powerful of known currents, called the *Gulf Stream.* Issuing from the Mexican gulf, the current rushes through the channel between Cuba and Florida, passing through the Straits of Bahama, with a velocity of from three to five miles an hour. It then continues its course along the shores of North America, as far as Newfoundland, where it is deflected to the eastward by an opposing current, which sets in from Baffin's Bay. Taking an easterly direction, the current passes the Azores, which it reaches in about seventy-eight days; and from thence it sometimes extends to the Bay of Biscay, and even to the western coast of the British Isles.

The course of the Gulf Stream is traced by its excess of temperature above that of the surrounding waters of the ocean. In the Gulf of Mexico, the waters become heated to a temperature about eight degrees higher than that of the ocean in the same parallel of latitude, and a large portion of the warmth is retained, long after the stream has poured its waters into the Atlantic. As it proceeds northwards, although its waters become cooled, yet it still maintains a higher temperature than the colder waters of the ocean in those more northerly latitudes, so that near Newfoundland, its temperature is also eight degrees above that of the adjacent sea, and even after crossing the Atlantic and entering the Bay of Biscay, it still retains an excess of five degrees above the waters of that part of the ocean. And, since it has been observed to arrive off the coast of Europe in the winter season, it is supposed that this remarkable current may tend to mitigate the cold of winter, in countries situated on the west of Europe. It is even considered probable, that the influence of the Gulf Stream extends to the sea near Spitzbergen, and that the large glaciers which are formed on those islands, are undermined and caused to quit their native shores, by the warmer water derived from this source. And, whilst the Gulf Stream is thus carrying a supply of warmth from the torrid to the frozen zone, the *Polar current* is taking a southerly direction, and conveying a volume of water from the arctic to the equatorial regions, probably imparting a low tem-

perature to Labrador, and tending to cool the waters of the tropical seas. We thus perceive that a mutual interchange is incessantly taking place by means of the waters of the ocean, between the heat of the torrid zone and the cold of the frigid zone, which by this wise adjustment, are made to balance each other.

The courses of the currents of the ocean are also traced by the vegetable productions which they drift to distant shores. Thus, fruits, portions of plants, and timber, the produce of tropical America, and of the West Indies, are occasionally cast on the shores of western Europe, as also on those of Ireland and the Hebrides. And on the other hand, the equatorial current conveys the productions of the Old World to the New. Thus, a great quantity of cork shavings, sufficient, according to Mr. Schomburghk, to furnish the inhabitants of Anegada with cork to attach to their fishing nets, are washed on the shores of that island. And since the cork tree is unknown as a native of the New World, but is indigenous in the south of Europe, and in Africa, it cannot but be supposed that the cork is drifted to that region by the great easterly current.

Some currents of the ocean are very local. Such is the perpetual current which sets into the Mediterranean Sea, through the Straits of Gibraltar. Such also is the current which flows into the same sea, from the Euxine or Black Sea. And such is the perpetual current which sets out of the Baltic Sea into the Northern Ocean.

Whirlpools appear to be caused by currents encountering submarine obstacles, which cause them to whirl round with considerable velocity. When the movement is rapid, the centre forms the most depressed portion of the whirlpool, and objects which are drawn within its reach, are engulfed or sucked in, at that point. Several small whirlpools, of sufficient power to whirl round boats of moderate size, occur among the Orkney Islands. Among the Western Islands, also, a whirlpool of some size occurs, which is called the Whirlpool of Coryvrechan; it is situated in the narrow channel between

Scarba and Jura, and is caused by opposing currents encountering a submarine rock of conical form, which rises abruptly from the bottom of the ocean, (which here has a depth of 600 feet,) to within 90 feet of the surface.

The long-celebrated whirlpool in the Straits of Messina,

> Deep Charybdis, gulphing in and out,

appears to have owed much of the terror with which it has been invested, to the ignorance and inexperience of the mariners by whom those seas were navigated in ancient times.

One of the most remarkable whirlpools in the European seas, is the Mälstrom, which is situated near the island of Moskoe, on the coast of Norway. This whirlpool is caused by the flood-tide setting from the south-west amongst the Laffoden Isles, which, especially when it meets with a strong gale from the north-west, produces a great agitation of the waves, forming a whirlpool, the roaring of which is heard at the distance of many miles. The Mälstrom is dangerous to vessels which may approach too near its disturbed waters; and it is said that whales and seals, when caught within its eddies, are unable to extricate themselves from destruction:

> When the dire Maelstrom in his craggy jaws,
> Engulfs the Norway waves with hideous sound,
> In vain the black sea monster plies his paws
> Against the eddy that impels him round,
> Racked and convulsed, the ingorging surges roar,
> And fret their frothy wrath, and reel from shore to shore.

The waters, like the face of the earth, teem with living creatures, and the bed of the ocean is scarcely less beautifully clothed with submarine vegetation, than the surface of the dry land is with verdant herbs and stately trees. Like the land, too, it has its hills and dales, and even its desert tracts; sandy plains extending for miles in some parts of the ocean's bed, apparently wholly destitute of vegetable productions. Some of the *algæ**, or marine plants, are adapted to flourish only in

* The Algæ tribe, properly speaking, comprehends not only marine plants, or sea-weeds, but also the *confervæ*, or those species which are inhabitants of fresh-water lakes and streams.

situations where they are within the range of the tides, and consequently are alternately covered by the waters, and subjected to the action of the atmosphere; whilst others inhabit the oceanic valleys, thriving at the remarkable depth of 1000 feet below the surface. The extraordinary size attained by some marine plants, in a great degree, however, accounts for this; as an instance of which we may mention the Macrocrystis pyrifera, said to vary in length from 500 to 800 feet, or more. Marine plants, not being subjected to the same vicissitudes of the seasons as land plants, are not liable to similar interruptions in their growth; which accordingly continues in winter as well as in summer, and in some species proceeds with great rapidity. It is supposed that marine plants derive their chief supplies of nourishment, from the water that encompasses them, and that, though like land plants, many of them have their particular *stations*, some being peculiar to sandstone rocks, others to chalk, &c., they are comparatively little dependent on the rocks to which they are attached, for aught besides the means of support. We however find, that they are provided with roots adapted to their peculiar wants. Thus, sea-weeds, which are designed to resist the force and agitation of stormy seas, possess roots peculiarly fitted to take firm hold of the rocks to which they are affixed, and which they grapple by means of extremely tough and thick fibres; whilst other species, which present a smaller surface to be acted on by the waves, or which are more short-lived, are usually attached by a simple shield or disc; and one species of *sargassum*, appears to be so wholly dependent on the water for its support, that it grows whilst floating in the water, and never has been found attached to any rock.

It is only in comparatively modern times that the algæ, or sea-weeds, appear to have been regarded as possessed of any utility; indeed, they are said to have been considered by the Romans as so utterly worthless, that anything useless was proverbially compared to algæ. In recent times, however, they have been turned to profitable account; and only a few years since, the manufacture of *kelp* from the ashes of burnt sea-

weed, chiefly of the *fucus* genus, was carried on in Scotland and its adjacent isles to so great an extent, that not less than 20,000 tons, sold at the average price of 10*l.* per ton, were annually made in that district alone. The kelp, which contains a certain proportion of carbonate of soda, was much employed in the manufacture of soap, and of common green bottle glass; but its use is now superseded by a better and cheaper preparation of that alkali, obtained from common salt. But though the *sea wrack* may no longer be employed for this purpose, it is not without its utility, furnishing, as it does, to the agriculturist, a highly important manure, both for pasture lands and for corn, potatoes, turnips, &c. Many sea-weeds also form articles of food, and this not only among uncivilized tribes, but even in the British Isles themselves. Thus, the *Chondrus crispus*, or Carrageen moss, is extensively used for that purpose in Ireland; and the *Laminaria digitata*, or sea-wand, is much eaten in Scotland, being cried about the streets of Edinburgh under the name of *tangle;* whilst the *Ulva latissima*, or green laver, not only forms a common dish in Scotland, and indeed in many parts of the globe, but even sometimes has been admitted at the fashionable tables of our great metropolis. Many species of sea-weed are soluble in water, forming a jelly or glue, applicable to various purposes. Thus, the Carrageen moss is both used as size by house-painters, and as a substitute for isinglass in making blanc-mange, &c.; and the *Fucus tenax*, which is a native of the China seas, is extensively used in the Celestial empire as a glue and varnish, especially in the manufacture of their celebrated lanterns, which, as well as many other articles formed of paper, of gauze, or of silk, are varnished over with this species of glue.

The great collections of floating sea-weed are not without their utility in the economy of nature, affording food and shelter to myriads of fish and mollusca. The most remarkable of these, and which indeed may be considered as forming one of the leading phenomena of the ocean, is the sea of floating weed, situated to the west of the Azores. This "weedy sea" occupies a zone having an average width of about 120 miles, and

and others, again, and this is the most generally received opinion, consider the herbaceous sea to be only the recipient of vast quantities of floating sea-weed, borne thither by the Gulf Stream; and hence it is frequently designated as the *Gulf weed.* The Portuguese call it the *Sea of sargasso,* and the Spaniards, the *Prairies of sea-weed.*

These large species of fucus appear to have their roots affixed to rocks and stones at the bottom of the sea, and rise to the surface from the depth of 200 or 300 feet, their gigantic fronds also trailing along the surface of the ocean for 40 or 50 feet. This sea-weed is commonly called "kelp" by seamen, that which is detached and floating, being called "drift kelp," and that which is still rooted on the rocks, being distinguished as "fixed kelp." The latter proves in many cases of extreme utility to navigators; for, when firmly rooted, it not only shows the set of the tide or current, but has the advantage of indicating shallow water, and thus of giving warning of impending danger. "Wherever there are rocks under the

water," observes Captain King, "their situation is, as it were, *buoyed* by a mass of sea-weed (usually called by seamen 'kelp') on the surface of the sea, of larger extent than that of the danger below. In many instances, perhaps, it may cause unnecessary alarm, since it often grows in deep water; but it should not be entered without its vicinity having been sounded, especially if seen in masses with the extremities of the stems trailing upon the surface*."

We have already briefly alluded to the hydrostatic apparatus with which some of the inhabitants of the waters are furnished, adapting them to the circumstances in which they are placed. Did our limits permit, it would be easy to multiply instances, all bearing on the same conclusion. But, although we may not at present pause

> To view in compass round
> All that the ocean holdes in his long armes;

we cannot refrain from briefly directing the attention of the reader, to the beautiful adaptation of the form and structure of fishes, to the properties of the liquid in which they are destined to reside.

"In order," says Dr. Roget, "that the fish may glide

* Needless alarm may, indeed, in some cases arise from other causes than supposed "fixed kelp," as the following amusing narration shows. A frigate was one day running into the Rio de la Plata, and her studding-sails set, when the look-out man at the mast-head reported breakers on the bow. The captain, believing such a danger could not have escaped the notice of the Spaniards, and having a tolerable chart of the river, suspected that it must be some floating object, and ordered the ship to be steered directly for it. The officers were on the alert; glasses were frequently directed to the spot; and all concurred in regarding it as a rock a little above water. Anxious looks were directed to the captain, whom they now considered to be running unnecessarily into danger; but that officer, though he kept carefully watching his approach, altered not his course, and just as the studding-sail boom was over the supposed fearful rock, the cetaceous monster, (for such it proved to be,) hastily made off, and rising again to blow, finally disappeared. It was observed to have an excrescence on its back, covered with shell-fish. The sea broke gently on its weather side, and appeared becalmed to leeward. And so perfectly did it resemble a rock, there can be little doubt but that it would have been inserted among the list of *vigias*, or warnings of danger.

through the fluid with the least resistance, all its vital organs have been collected into a small compass, and the body has been reduced into the shape of a compact oval, compressed laterally, and tapering to a thin edge, both before and behind, for the purpose of readily cleaving the water as the fish darts forward, and also of obviating the retardation which might arise from the reflux of the water collected behind. With a view to diminish friction as much as possible, the surface of the body has been rendered smooth, and the skin impregnated with oil, which defends it from injurious impressions, and at the same time prevents the water from penetrating into its substance." The importance of these provisions will be evident, when we consider the density of the medium which fishes have to traverse; but so admirably are their frames adapted to the conditions in which they are placed, that they seemingly dart through the water with as much ease as a bird flies through the air, performing long journeys with the utmost rapidity, and without apparent fatigue. Thus, according to Dr. Roget, "the salmon has been known to travel at the rate of sixteen miles an hour, for many days together; and sharks often follow ships across the Atlantic, not only outstripping them in their swiftest sailing, but playing round them on every side, just as if the vessels were at rest."

Thus do we find that the world of waters teems with evidences of unerring wisdom, directed to the promotion of the most beneficial purposes. By the attraction of cohesion, the particles of water are held together, so as to form a liquid mass; whilst by the process of evaporation, continually in progress, this liquid mass is divided into atoms, and thus separated from any extraneous matter with which it may have become associated, and which would tend to deteriorate its quality; being, however, ready, when thus purified, to be again united by the same attraction of cohesion. By the attraction of gravitation exercised by the solid parts of the earth, again, water is held

in its place on the terrestrial globe, and by the influence of the same law exercised by the heavenly bodies, the great primary wave is formed, giving rise to the ebb and flow of the tides. By the law of equilateral pressure, water maintains a level surface; whilst, owing to the mobility of its parts among each other, it yields to the pressure of winds, or other disturbing causes, which prove of the highest utility for its preservation in a healthful condition, by the consequent interchange of one portion of water with another, and the removal and dissolution of decaying organic matter. We have also seen that the saline contents of the ocean appear to conduce to the salubrity of this vast mass of waters; and that the inhabitants of the great deep, are remarkably adapted to the medium in which they move, and to the station assigned them in the universe. Such is a brief recapitulation of some of the leading features presented to our admiration in the subject which has now engaged our attention. Well then may we exclaim with the Psalmist: "They that go down to the sea in ships, and occupy their business in great waters; these men see the works of the Lord, and his wonders in the deep." Well may we say, with Bishop Hall: "O God, the heart of man is too strait to admire enough, even that which he treads upon: What shall we say to Thee, the Maker of all these?" Or, to use the words of the Russian poet, Derzhavin:

In its sublime research, philosophy
May measure out the ocean-deep—may count
The sands, or the sun's rays—but God! for Thee!
There is no weight nor measure.—none can mount
Up to Thy mysteries. * * *

* * * * * *

Thou art, and wert, and shalt be! Glorious! Great!
Life-giving, life-sustaining Potentate!
Thy chains the unmeasured universe surround;
Upheld by Thee, by Thee inspired with breath!
Thou the beginning with the end hast bound,
And beautifully mingled life with death!

THE END.

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